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The
GEOLOGY & STRUCTURE
of the
LETHBRIDGE COAL FIELD

1947
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I.D. Crawford
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GRADUATE SCHOOL

The undersigned hereby certify that they have read, and recommend to the Committee on Graduate Studies for acceptance, a dissertation on "The Geology and Structure of the Lethbridge Coal Field", submitted by Ian Douglas Crawford, B.Sc. in partial fulfilment of the requirements for the degree of Master of Science.

THE GEOLOGY AND STRUCTURE OF THE LETHBRIDGE COAL FIELD

by

Ian Douglas Crawford, B.Sc.

Department of Geology

UNIVERSITY OF ALBERTA

Edmonton, Alberta April, 1947

Thesis
1947
#7

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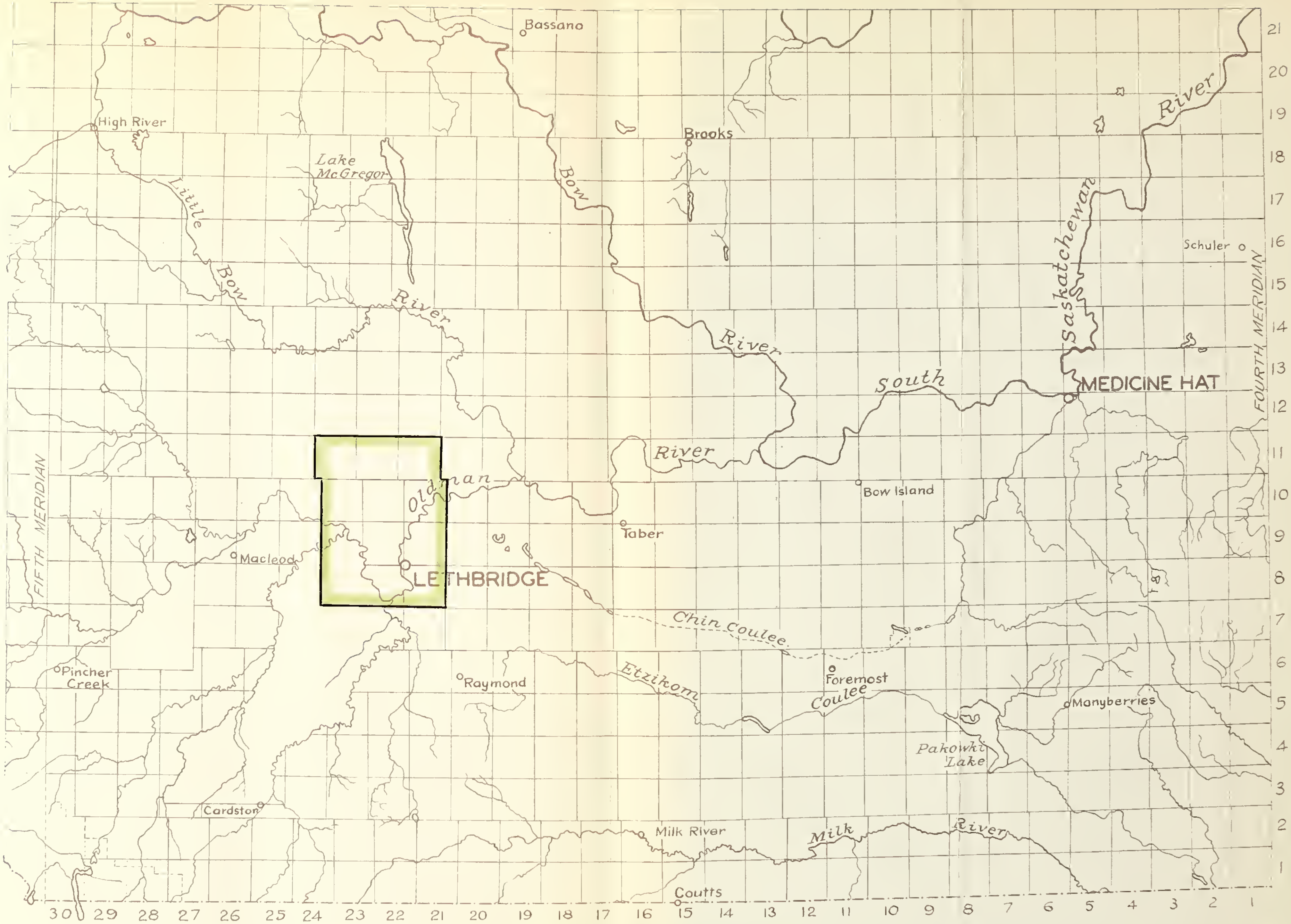


LOCATION OF LETHBRIDGE AREA

1 inch = 18 miles

GEOLOGY AND STRUCTURE OF THE LETHBRIDGE COAL FIELD

CHAPTER I

INTRODUCTION

Since the first mine was opened at "Coal Banks" on the Oldman River, there has been a steady development in the mining industry to such an extent that it is now the leading bituminous coal producing area on the plains of Alberta. Over the years, passing reference to the geology of the area has been included in various reports, but no single publication has dealt with the Lethbridge Coal Field specifically. This has resulted in the accumulation of a wealth of information as mining operations progressed. It is intended that this thesis will serve to correlate these data into a form which will make it of practical use, to those interested in this area.

Extent of Area

The area described in this report lies in southwestern Alberta and comprises an area of approximately 450 square miles. More exactly, it may be defined as including townships 8,9,10 and 11 between ranges 21,22 and 23, all west of the 4th Meridian. It does not correspond to the Lethbridge coal area as outlined by J.A. Allan on the map of the coal areas of Alberta (4,

Map #18, 1940) being somewhat less in areal extent.

Description of Area

The city of Lethbridge is the largest centre in the district, serving a large, surrounding agricultural and mining area. A number of smaller towns are to be found throughout the district. Monarch, Kipp and Picture Butte are typical farming towns on the Canadian Pacific Railway with elevator facilities for grain storage. Diamond City, and Coalhurst were established near to centres of mining operations. They are now practically deserted, since in both cases, the mines have been abandoned.

The area is well serviced by the Canadian Pacific Railway. Two lines from Calgary, join the main line from the Crowsnest Pass, one at Macleod and the other at Kipp. The railway passes through Lethbridge, crossing the Oldman River by means of a high trestle bridge, just west of the city. From Lethbridge, one branch continues east through Taber to meet the main line to Winnipeg at Medicine Hat, while another runs southeast to Coutts near the International Boundary and on into Montana.

There is an excellent network of roads throughout the district and the main highway from Calgary is

surfaced. It approaches Lethbridge from the west through Monarch and Kipp from Macleod. A narrow bridge has been constructed across the Oldman river about half a mile north of the railway trestle. Roads fan out from Lethbridge in all directions, several, serving larger communities to the south en route to the United States as well as to the east through Taber to Medicine Hat.

Drainage

The main drainage feature is the Oldman river, which forms part of the Saskatchewan-Nelson system emptying into Hudson Bay. Three streams, namely the Oldman, Castle and Crowsnest rivers, join in township 7, range 1, west of the 5th Meridian to form the Oldman river. Pincher Creek flows into the Oldman near Brockett. Belly River, which rises near Chief Mountain, Montana is joined by the Waterton river in township 7, range 25, west of the 4th Meridian and meets the Oldman river near Monarch. St. Mary river rises in Montana from St. Mary lakes and empties into the Oldman river in Township 8, range 22, west of the 4th Meridian. Small side streams enter the Oldman river during the spring run-off but are intermittant in character. The Oldman river leaves the area in township 10, range 21, west of

the 4th Meridian.

Topography

The topography may be divided into two separate units, namely the river valleys, and the flat plains of the general prairie level. The Lethbridge area is within the western limits of the great plains province, which extend eastward from the foothills across Alberta. The flat surface above the river valleys is only very gently rolling. The average elevation for the district ranges between 3000 feet and 3100 feet. There is a gradual rise to the northwest to 3300 feet in township 11, range 22, west of the 4th Meridian. In the region of the Blood Indian Reserve in the Southwest corner of the area, a gently rising hill reaches an elevation of 3500 feet. These hills are underlain by sandstones of the St. Mary River formation. These beds are of sufficient hardness to retard the forces of erosion relative to the remainder of the area which is underlain by the softer sandstones and shales of the Bearpaw and Oldman formations. The general level is here, 300 to 400 feet lower. This uplands division is immediately underlain by deposits of glacial drift, which is known, by test borings, to vary in thickness. The base of these deposits is fairly uniform in elevation, averaging

2800 feet above sea level. The pre-glacial topography was evidently fairly flat in this area.

The river valleys are lower than the general prairie level and attain a maximum depth of 300 feet. The valleys are flat bottomed and trough shaped, with the character of the banks varying with the underlying bed-rock. From the Monarch fault zone to the mouth of the St. Mary River and from Lethbridge to Diamond City, the Oldman river passes over Bearpaw shales. These shales are easily eroded, which results in a broad valley, averaging a mile in width. Usually, the outcrops of Bearpaw shale are intermittant and occur only where the river is actively eroding its banks. Bentonite beds in the Bearpaw act as slippage planes when wet, and the slumping, which results in a step-like topography on the sides of the valley, is common.

From the mouth of St. Mary River to Lethbridge and below Diamond City, the sides of the valley are composed of sandstones of the Oldman formation. Here, the valley narrows to about a half a mile in width with fairly steep banks. In places sheer walls over 100 feet high are developed. The exposures are more numerous but not continuous as the sandstones are very lenticular, and grade laterally into soft silty shales which are not

conducive to good exposures.

Small side streams enter the Oldman river, but are generally intermittant in character and serve to drain the spring run -off.

Maps

A series of maps have been prepared from published sheets of the Geological Survey of Canada and of the Office of the Surveyor General. In addition, a map issued by the Alberta Petroleum and Natural Gas Conservation Board, was used in the compilation. The following list will serve to indicate the sheets from which the topography, drainage and well locations were obtained:

Office of the Surveyor General;

Sectional Sheet #15 - Lethbridge

Sectional Sheet #65 - Macleod

Scale 1" = 3 miles.

Geological Survey of Canada;

Map #565A - Taber

Map #566A - Foremost

Scale 1" = 4 miles.

Alberta Petroleum and Natural Gas Conservation Board;

Southern Plains of Alberta

Scale 1" = 4 miles.

Included in this thesis are two maps of the Lethbridge area (Encl. #1 and #2) on a scale of 1" equal 1 mile. They include townships 8 to 11, ranges 21 to 23, west of the 4th Meridian. Enclosure #1 has been used to outline the distribution of the outcropping formations in the district. The locations of the towns and railways have been included as well as the physical features of the topography and drainage.

The second map has been used as an outline on which to plot the structure of the Lethbridge Coal Field, as illustrated by structural contours. The locations of the towns and main features of the drainage have been plotted on this sheet.

A third sheet, covering an area including townships 2 to 14, ranges 14 to 24, west of the 4th Meridian, is on a scale of 1" equal 4 miles. This sheet has been used as a base for three maps (Encls. #4,5,6) which show the regional structure by means of structural contours. The main drainages and the larger towns have been included on these sheets.

Acknowledgements

Any merit which this thesis may possess is in large part due to the splendid co-operation of the many members of the mining profession, both in Lethbridge and Edmonton,

and others, who have supplied information on all phases of the problem.

The problem was suggested by Dr. J. A. Allan, Professor of Geology, University of Alberta. It was under his supervision that the maps, included in the report, were prepared. In addition, he supplied valuable information, acquired on his many visits to the area. The writer has enjoyed valuable discussions with Dr. P. S. Warren regarding the stratigraphy of the district. He also examined the fossils which were collected in the field. Dr. R. L. Rutherford has outlined important structural features of the southern plains which have a bearing on the structure of the Lethbridge area. To these members of the Department of Geology, University of Alberta, the writer is deeply indebted. Their suggestions have been invaluable to a beginner in the field of Geology.

The writer wishes to extend his thanks to Mr. J. Crawford, Chief Inspector of Mines for Alberta and to Mr. E. Morgan, District Inspector of Mines for much of the information embodied here. This information was contained in the mine plans and records of the Mines Branch and facilities were provided the writer to obtain this data. Mr. J. Davidson, General Manager of

the Lethbridge Collieries Ltd., has contributed much information in regard to exploratory boring.

To all mine operators and others who have assisted in any way in this investigation, the writer is indeed grateful and extends his sincere thanks.

Previous Work

The earliest record of geological observations on the southern plains of Alberta are to be found in the journals of the Palliser Expedition (44, 1863). The notes on the geology were recorded by Dr. Hector, and were based on his observations during explorations in the Northwest as a member of the expedition under the leadership of Captain John Palliser. These explorations were carried on over a period of four years from 1857 to 1860. In August of 1859, Dr. Hector left the Cypress Hills and proceeded west towards the mountains. The party dropped into the valley of the Bow River and followed it for some distance before crossing the Belly River (Oldman River) about two miles from its mouth. Dr. Hector wrote "at Belly River sections showed the sandstone clays with lignite resting on dark brown sandy clays". These beds are now included in the Foremost formation.

No further additions were made to these observations until 1874, when G. M. Dawson accompanied the

Boundary Survey as Geologist. The results of his work were published in 1875 (15), and furnish a description of the geology from the Lake of the Woods to the Rocky Mountains in the region of the 49th parallel.

Dawson returned to the southern plains to map the region of the Bow and Belly Rivers. His classic description was published in 1885 (18) and has formed the keystone of all subsequent work. He was particularly interested in occurrences of coal and described, in some detail, the seams found outcropping in the vicinity of Coal Banks.

Dawson, in a preliminary report of the Geological Survey of Canada in 1883 (16) defined the Belly River formation as a series of fresh and brackish water beds conformably overlain by the Pierre shales and conformably overlying the "Lower Dark shales" (Colorado). He recognized a difference in appearance between the lower and upper part of his Belly River formation and divided it in two parts. An upper pale colored portion and a lower more distinctly banded, darker series. He refers to these divisions as the "Pale" and "Yellowish" beds respectively. In defining his Belly River formation, Dawson failed to recognize the difference between a

marine shale exposed in Pakowki coulee, and his "Lower Dark shales" outcropping in the Sweetgrass Hills, and correlated the two.

In 1905, T. W. Stanton and J. B. Hatcher (64) traced the Judith River and related formations from Montana, northward into southern Alberta. They showed that the dark shales of Pakowki coulee were the equivalent of the Claggett shale of Montana. At the same time the continental beds above this shale were correlated with the Judith River formation of Montana.

In 1914 Dowling (24) reported on the coal fields of the west and included brief reference to the Lethbridge area. In 1915 (25) he indicates on the basis of fossils that "Lower dark shales" and the shales of Pakowki coulee are not the same and suggests that the stratigraphy should be revised. Dowling in 1916 reported on the artesian water of the southern plains (26).

In 1917, Dowling (27) revised the stratigraphy of the southern plains and named several formations. He used the term Belly River to include all the formations embraced by Dawson's original definition of the Belly River formation, i.e. the beds lying between the top of the Alberta formation and the base of the Bearpaw formation. The marine shales of Pakowki coulee were named

the Pakowki formation. The Pale and Yellowish beds were divided on the basis of "a certain coal seam that in various places is important enough to be mined". The descriptive term of Dawson was used by Dowling for the beds lying above the coal series and below the Bearpaw shales. He applied the term Pale beds for this uppermost section of his Belly River series. The Foremost beds overlie the Pakowki formation to the base of the Pale beds. To the continental sandstones and shales between the top of the Alberta formation and the base of the Pakowki formation, Dowling applied the name "Milk River" and raised them to the status of a formation. Stanton and Hatcher, in 1905, had shown that these sandstones were the equivalent of the Eagle sandstone of Montana.

Dowling quoted Dawson's description of the coal deposits along the Oldman River in the vicinity of Lethbridge, as published in 1884. He included a short description of the progress that had taken place in the field since that time and included a log of the well drilled at Lethbridge prior to 1913 for water and gas. The well was carried to a depth of 2220' and reached the Colorado formation.

A survey of the southern plains was begun in 1923 and field mapping was carried on during each year including the summer of 1926. Memoir 163 (75) was published in 1930 by M. Y. Williams and W. S. Dyer although P.S. Warren and E. J. Whittaker mapped parts of the area. The fault zone at Monarch and the faulting in the coal seams at Lethbridge is briefly described. A new interpretation for the Belly River series was suggested which would restrict it to the Pale and Foremost beds of Dowling.

In 1931, the Donaldson Bogart Dowling Memorial Symposium on the Stratigraphy of the Southern Plains of Alberta was published by the American Association of Petroleum Geologists. It consists of 14 papers presented by members of the Alberta Society of Petroleum Geologists. These papers review the stratigraphy of southern Alberta and indicate some of the problems that still remain to be solved.

L.S. Russell (51) studied the geology of the eastern part of the Blood Indian Reserve and a summary report was published by the Geological Survey in 1931. It included a structural map of the Belly River formation in this area and a section showing the disturbed beds of the Monarch fault zone. He considers the sandstone which occurs below the typical St. Mary River formation to be stratigraphically lower than the Fox Hills

sandstone of south western Alberta and suggests the name "Blood Reserve" sandstone be adopted for this unit. The type section is located on St. Mary River.

During the years 1931, 1934, 1935, 1936 and 1937 L. S. Russell and L. W. Landes remapped the southern plains in more detail. The results of their work were published as a memoir by the Geological Survey of Canada in 1940 (54). J. C. Sproule, one of the senior assistants, mapped the geology along the Oldman River and prepared a structural contour map of the Lethbridge area. Sproule's work is included in this memoir.

Due to the ambiguity which had developed regarding the definition of the Belly River series, Russell and Landes avoid the use of the term and elevate the Pale and Foremost beds to the status of formations. The substitution of the term "Oldman" for "Pale" was also suggested on the grounds of its geographical, rather than descriptive significance.

Annual reports (78) have been published by the Mines Branch of the Province of Alberta since 1918. These reports contain information on the Mining industry of the Province and include tabulations of coal production by districts and information on operating mines. Prior to 1918, this information was included with the annual report issued by the Department of Public Works.

statistics on the coal production and mines in the Lethbridge field may be found in these compilations.

The Annual Report of the Mines Branch for 1924 includes a tabulation of all the mines which had been in operation in the province prior to 1924, in addition to the information on the operating mines for that year. Reports issued in 1943, 1944 and 1945 contain special reports on each of the Inspectorate Districts of the province, compiled by the District Inspectors of the Mines Branch.

CHAPTER II

SUMMARY

The Lethbridge area is situated in southwestern Alberta and lies within the western limit of the great plains. The largest centre is the city of Lethbridge which serves the rich, surrounding mining and agricultural district. The area is readily accessible, being well serviced by the Canadian Pacific Railway, and traversed by an excellent network of roads.

The outcropping formations are Upper Cretaceous in age, consisting of Oldman, Bearpaw, Blood Reserve and St. Mary River strata. The older formations are known only from deep boring, and the strata penetrated by Keho #1 in lsd 2-17-11-22-4 are used in describing these deep lying beds. This bore hole reached the Palaeozoic.

The Oldman formation underlies the eastern part of the area. It consists of non-marine, light grey sandstones and shales, with coal seams in the upper part. The Bearpaw-Oldman contact is gradational and the Lethbridge coal seam occurs in the lower part of this transition zone. This coal seam averages 4 feet in thickness although variations from this figure are common. The Oldman formation is 590 feet thick.

The central part of the area is underlain by marine

shales of the Bearpaw formation. It contains three sandstone members in the upper part, namely, the Magrath sandstone, 210 feet above the base, the Kipp sandstone, 370 feet above the base and the Ryegrass sandstone, 84 feet below the top. The lower part of the formation is predominantly dark grey, shale with no sandstone members developed. The Bearpaw is 730 feet thick at Lethbridge.

The western part of the area is underlain by the Blood Reserve and St. Mary River formations. The Blood Reserve formation is marine and thins to the north. At Monarch, it is 40 feet thick, consisting of one massive sandstone unit with thin stringers of interbedded shale.

The St. Mary River formation is non-marine, and lies above the Blood Reserve formation. The contact is gradational, and coquinas of brackish water molluscs occur within this transition zone. Only the lower part of the St. Mary River formation outcrops within the area, consisting of light grey, massive, sandstones and grey shales.

Saskatchewan gravels of late Pliocene (?) age occur above the Upper Cretaceous formations. Quartzite pebbles are the most common constituent with lesser amounts of aregillites, sandstones, conglomerates and igneous pebbles. The gravels are usually 15 to 20 feet

thick. The Lethbridge area is mantled with a thick deposit of Keewatin glacial drift, in part, lying above the Cretaceous strata. It also occurs above deposits of Saskatchewan Gravels.

The Lethbridge district lies on the west limb of the Sweetgrass arch and the east limb of the Alberta syncline. The regional structure of the district is monoclinal, with the regional dip to the west. The detailed structure of the district consists of a series of northwesterly plunging anticlines and synclines with the prominent structural feature of the Lethbridge coal field consisting of a gentle syncline, with its axis crossing the Oldman river in the N.E. ¼ of section 24-9-22-4 and trending about N. 45° W.

Numerous minor faults cut the coal seams, with an average displacement of 4' to 6'. These breaks may be due to normal, reverse or pivot faults. Large normal faults, with displacements as great as 100', are exposed in the valley of the Oldman river. They involve the Bearpaw and Oldman formations at the surface, but are not believed to carry to depth. The Monarch fault zone consists of a series of fault blocks separated by steep west dipping thrust faults. The faults strike in a general north-south direction, varying from N. 25° W. to N. 20° E.

The minor faults occur most commonly trending in two main directions. The first coincides with the strike of the local folding (N. 45° W.) and normal to it (N.45° E.). The second is oblique to the axes of the folds in a zone between N.15° W. and N.15° E. The normal component is not well developed but a fault of relatively large displacement trends N.75°E. in section 1-9-22-4.

The folding in the Lethbridge area occurred during the uplift of the Rocky Mountain Revolution in late Eocene time. The stresses acted as a couple, in a general northeast - southwest direction. The minor faults and larger normal faults which are parallel to the folding, were formed by these compressive forces.

The folds and the faults parallel to the axes of the folds (N.45°W.) are the result of compressive forces. The faults occurring normal to the axes of the folds are due to tensional stresses. The faults trending obliquely to the axes of the folds between N.15° E. and N.15° W. are the result of shearing stresses. The faults at Monarch strike between N.25° W. and N.20° E. and are also considered to result from these shearing stresses.

The release of pressure after the folding accompanied by adjustments of the strata along planes of weakness, doubtless resulted in minor faulting. Uplift of the plains region during later periods may have contributed to the faulting, which would also occur, in the directions of

weakness as determined during the period of mountain building.

CHAPTER III

DESCRIPTIVE GEOLOGY

The formations outcropping within the area of this report are of Upper Cretaceous age. Exposures occur only in the river valleys, below the unconsolidated deposits. The distribution of the formations is outlined on the Geological Map accompanying this report. (Encl. #1). Information on the formations below the Oldman formation, composing the oldest outcropping strata in the district, has been obtained from logs(33) and samples of Hudson Bay Oil and Gas Co., Keho #1. This is the deepest well in the district on which subsurface data are available. A brief description of the older formations is included, with a more comprehensive account of the outcropping strata.

Description of Geological Map

Lack of exposures over a large part of the area has made an exact delimitation of the formations impossible. Most of the contacts have of necessity, been projected on the basis of the underlying structure, as plotted from bore hole data.

The formations follow a regular sequence from the Oldman formation in the eastern part to the St. Mary River formation in the west. The formations trend north-

TABLE OF FORMATIONS

ERA	PERIOD	AGE	FORMATION	THICKNESS	LITHOLOGY
CENOZOIC	Recent Quaternary	Pleistocene			River, gravels, silts and sands Boulder till and silts
			Erosion interval		
	Tertiary	Pliocene ?	Saskatchewan Gravels	15-20'	Quartzite gravels
			Erosion interval		
MESOZOIC	Upper Cretaceous	Maestrichtian	St. Mary River		Non-marine Sandstone, grey and shale
		Campanian	Blood Reserve	40-70'	Sandstone, marine
			Bearpaw	730'	Shale, grey and sandstone, marine
		Santonian	Oldman	590'	Sandstone and silty shale, non-marine
			Foremost	480'	Sandstone, shale, coal, non marine
			Pakowki	100'	Shale, dark grey, marine
			Milk River	200'	Sandstone, grey, non-marine
		Coniacian Turonian	Alberta	1900	Shale, dark grey, sandstone, marine
		Cenomanian	Erosion interval ?		
	Lower Cretaceous	Albian Aptian Barremian ?		550'	Shale, green and maroon, Sandstone and sandy shale, coal
			Erosion interval		
	Jurassic	Callovian	Ellis	144'	Shale, dark grey, marine
			Unconformity		
	Carboniferous	Mississippian	Madison	1100'	Limestone

south across the area, with a slight difference in the width of the outcrop due to local variations in the regional dip. The dips are less steep towards the north, which is a reflection of the plunge of the Sweetgrass Arch. This accounts for the somewhat wider width of outcrop, exhibited by the formations in this region.

Palaeozoic Era

Carboniferous Period

Mississippian Epoch

Madison Formation

Name

A. C. Peale (46) named the Madison formation in 1893 after a detailed examination of linestones occurring in the Three Forks quadrangle of Montana. Collier and Cathcart (11) divided the Madison rocks into the Mission Canyon limestone and a lower unit called the Lodgepole limestone. Moore (43) in 1931, recognized a twofold division of the Carboniferous limestones of Alberta and Hume, 1933 (33) shows that the two divisions can be traced northward from the International Boundary. Russell and Landes have suggested a correlation with the Montana section on the basis of lithology and the relation to the adjacent strata.

Lithology and Thickness

In the Lethbridge area, Keho #1, penetrated the upper 12' of the Madison formation. It consists of dark grey, limy shale and cherty limestone. An exact thickness of the Madison at Lethbridge is not known, and wells drilled in surrounding areas show a considerable variation. Mid Continent Universale #1 in lsd. 12-17-9-17-4 passed through 1010' of Madison into the Devonian. Northwest West #1, 18 miles southwest of Lethbridge in lsd. 3-20-5-23-4 reported a thickness of 1182'. The Hudson Bay Oil and Gas Co., Eyremore #1 well, in lsd. 1-26-17-18-4 found the Madison had thinned to 768'. Warren (66) measured 3800' of Mississippian beds overlying the Devonian at Banff.

These thicknesses indicate a thinning from west to east and from south to north. This is due chiefly to a northeastward bevelling by erosion prior to the deposition of the Jurassic sediments. An estimate of 1100' as the thickness of the Mississippian at Lethbridge is here suggested. This is based on an average rate of thinning of 6' per mile to the northeast.

Age

The fauna of the Madison group have not been studied in detail but preliminary work by Sloss and Hamblin (61) in 1942 indicates a Kinderhook and Osage

age for these limestones.

Erosional Unconformity

Overlying the Madison are beds of Jurassic age, with erosion of the limestone surface occurring during this hiatus. The amount of erosion is indicated by the thinning and disappearance of the Madison limestone to the northeast of the Lethbridge area.

Mesozoic Era

Triassic Period

Strata of Triassic age have not been identified under the southern plains of Alberta. It is possible that this was either a period when the area was above sea level, or the deposits were subsequently eroded.

Jurassic Period

Ellis Formation

Name

The Ellis formation was named by A. C. Peale and G. P. Merrill in 1893 (46). It was applied to marine Jurassic in the Three Forks area of Montana. The Ellis is known from deep borings in Montana and southern Alberta. J. O. G. Sanderson (58) described a section of Ellis at East Butte in the Sweetgrass Hills. He notes that "on the plains of southern Alberta and northern Montana, the Ellis is known from well samples". He implies that the Jurassic of the southern plains of Alberta is equivalent

to the Ellis of Montana. Russell and Landes, 1940, (54) also suggest this correlation.

Lithology and Thickness

In Keho #1 the Ellis is 144' thick and lies unconformably on the Palaeozoic. It consists of dark fissile shales with some thin limy bands and dark green fissile shales containing pyrite. A belemnite bed occurs about 50' above the base of the formation. The belemnite bed is a consistent horizon in the Ellis of the southern plains.

Age

C. H. Crickmay in 1931 (13) suggested that the exposures on Sage Creek, Montana, are of Callovian age, i.e. a portion of the lower part of the upper Jurassic. On the grounds of proximity, Russell and Landes (54) suggest a Callovian age for the Jurassic of southern Alberta.

Cretaceous Period

Lower Cretaceous Epoch

Name

No specific formational name has been assigned to the lower Cretaceous of the southern plains. In Montana, the equivalent beds are termed Kootenai. In the southern foothills of Alberta, a two-fold division

is recognized. The upper beds are known as the Blairmore formation and the lower coal bearing beds, the Kootenay Formation. This twofold division is not recognized in the strata underlying the plains and the term Blairmore-Kootenay is sometimes used. Hume(33) in 1933 notes a thinning of the Kootenay eastward and commonly the term Blairmore - ? Kootenay is applied to this series.

Lithology and Thickness

At Keho #1, 550' of Lower Cretaceous strata were penetrated. These beds consist of continental, green and maroon, fissile shales and sandy shales. Lesser amounts of light grey, fine to medium grained sandstones are also present and dark brown ironstone bands occur at irregular intervals. A coal seam was encountered 340' from the top of the formation. Abundant carbonaceous material occurs throughout and pyrite is common. Oolites occur in shaly sandstone 100' below the upper contact.

The contacts are both transitional and somewhat indefinite.. The upper boundary is drawn where the first red and green shales are encountered below the marine Alberta shale. The lower contact is drawn at the first appearance of the dark marine shale of the Ellis.

Age

Lack of diagnostic fossils makes an age determination difficult for the Lower Cretaceous of the plains. The Kootenay-Blairmore of the foothills includes the upper part of the Barremian, Aptian and Albian. It seems probable that the time interval would be approximately the same for the western part of the southern plains.

Upper Cretaceous Epoch

Alberta Formation

Name

The name "Alberta Shale" was applied to a thick section of dark grey marine shales and sandy shales lying between the Blairmore and Belly River formations of the foothills by G. S. Hume, 1930 (32). It consists of three members, an upper and lower shale separated by a sandstone and shale member known as the Cardium sandstone. In the plains, where the Cardium is not recognized, the shale series is called the Alberta formation.

Lithology and Thickness

At Keho #1, the Alberta formation is approximately 1900' thick. In the southern plains, the formation consists of an upper shale and sandy shale and a lower arenaceous part known as the Blackleaf

member. At Lethbridge, the upper shales are dark grey, fissile and contain scattered ironstone bands and nodules. Bentonite occurs in thin beds. Pyrite is common and the sandy shales are often glauconitic. The lower 550' of the formation contains an appreciable amount of sandstone and sandy shale. These sandstones are light grey and range from fine grained to conglomeratic. Glauconite is not uncommon. Interbedded shales vary from dark grey to green to maroon and in part appear non-marine. Limy ironstone is common and some traces of bentonite may be noted. The basal part shows traces of plant remains. This lower part is probably equivalent to the Blackleaf member.

The upper and lower(?) contacts are transitional. The upper boundary is usually marked by the occurrence of a white speckled shale, but it becomes difficult to recognize to the west and this is the case at Lethbridge where no "white specks" were observed. The lower boundary is usually taken at the first appearance of the non-marine shales of the Lower Cretaceous.

Age

The Alberta shale of the foothills has been zoned on the occurrence of macro-fossils, 1928,(70) 1934, (72). These fossils are mainly ammonites and Inocerami. The lower Alberta shale of the foothills

contains an abundant fauna consisting of Prionotropis, Watinoceras and Inoceramus labiatus. This unit has been correlated with the Turonian of Europe. The Upper Alberta contains Scaphites ventricosus and Inoceramus pontoni and is equivalent to the Coniacian-Emscherian of Europe. A. T. Collier, 1929, (10) published a list of fossils collected by borings in the Kevin-Sunburst Field, Montana. He shows that Inoceramus labiatus occurs within a zone 1000 to 1100 below the top of the formation, and Scaphites ventricosus from 20' to 750' below the top. It would seem that the Alberta formation is equivalent to the Turonian and Coniacian-Emscherian of Europe. More recently, G. M. Furnival, 1946, (30) has included the Turonian in the Lower Cretaceous on the basis of micro faunas described by Wickendon.

Milk River Formation

Name

The Milk River formation was named by Dowling in 1917,(27). He revised much of the stratigraphy of the southern plains, and recognized that the Milk River sandstones were below the Pakowki shale and thus not part of the Pale and yellowish beds of Dawson.

Lithology and Thickness

At Keho #1, the Milk River formation is approximately 200' thick. It is a continental wedge con-

sisting predominantly of light grey, salt and pepper, fine to medium grained sandstone, with thin shaly streaks. It contains scattered plant remains.

The Lower contact with the marine Alberta formation is gradational, through a transition series of sandstone and shales, with shales becoming predominant. The upper contact is also gradational from marine shales of the Pakowki to the non-marine sandstones of the Milk River.

The Milk River formation is an important aquifer. It serves as a source of artesian water for a large area of the southern plains. Its possibilities as a source of artesian water were first suggested by Dowling in 1916, (26) after carrying on detailed mapping of the formation.

Age

The Milk River formation contains no distinctive fauna but Desmoscaphites bassleri has been collected from the Virgelle sandstone of Montana.(54)The Virgelle is equivalent to the lower Milk River. This form is used to correlate with the Santonian of Europe and the Milk River is thus equivalent to part of the Santonian.

Pakowki Formation

Name

The Pakowki was named by Dowling in 1917 (27).

He recognized it as a separate formation, occurring above the Milk River sandstones and thus not correlative with the "lower dark shales" of Dawson.

Lithology and Thickness

At Keho #1, approximately 100' of Pakowki shales were penetrated. The formation thickens to the east and thins, and is not recognized in the foothills to the west. It consists predominantly of dark, fissile marine shale containing glauconite in small amounts. Streaks of light grey sandstone are common as well as scattered ironstone bands.

Age

A large fauna is known from the Pakowki formation which also contains *Baculites ovatus*. *Baculites ovatus* is used as a zone fossil and is generally regarded as Santonian in age. The Pakowki formation is equivalent to part of the Santonian of Europe. Landes, 1940, (54) studied the fauna of the Pakowki and named it the "*Baculites obtusus*" zone. The relation of this form in correlating with the European section is not – yet known.

Foremost Formation

Name

In 1917, Dowling (27) applied the name "Foremost beds" to the Yellowish beds of Dawson. He considered

that the presence of several coal seams in the lower part made the Foremost sufficiently important to map separately. Previously the Pale and Yellowish beds had been mapped together. Russell, 1940, (54) elevated the Foremost beds to the status of a formation.

Lithology and Thickness

At Keho #1, the Foremost is about 480' thick. It is composed of dark carbonaceous shale and lesser amounts of fine to medium grained, grey, salt and pepper sandstone, with sandy shales. Coal seams occur at the top and near the base of the formation. Thin coaly lenses and pockets are abundant throughout the formation. Ironstone bands are not uncommon.

The Oldman-Foremost contact is not sharp, and an arbitrary boundary must be taken. Dawson, 1885, (18) and Dowling, 1917, (27) place the upper contact at a zone of dark carbonaceous shale and coal seams. Williams and Dyer, 1930, (76) and Russell and Landes, 1940, (54) use the base of a thick massive, lenticular sandstone as the boundary. At Lethbridge, dark carbonaceous shale with thin coaly partings was taken as the contact. No set rule may be applied as conditions vary greatly in different areas. The Foremost-Pakowki contact is gradational and is drawn at the

first appearance of marine shale.

Age

The age of the Foremost will be considered with the dating of the Oldman formation.

Oldman Formation

Name

The formation was named by Russell and Landes(54) in 1940. It was suggested as a substitute for the term "Pale beds", which applied to the upper part of the Belly River series of Dawson. This nomenclature is preferable, as it has a geographic rather than a descriptive significance.

Distribution

The Oldman formation is the oldest formation found outcropping in the area of this report. In traversing down the Oldman river, it is encountered rising above the level of the valley floor near the mouth of St. Mary River. Exposures of the sandstones and shales of this formation form a large part of the walls of the valley to the vicinity of the railway bridge across the river at Lethbridge where it dips below river level on the southwestern limb of a low synclinal area which extends for a distance of six miles below Lethbridge. In Section 6, township 10, range 21, west of the 4th meridian, near Diamond City, beds of

the Oldman formation may be seen on the west side of the river. They are here in fault contact with beds of the overlying Bearpaw shales. Exposures may be observed on the sides of the valley below Diamond City.

Lithology

The Oldman formation consists of a series of sandstones, shales, sandy shale, ironstone and a coal series near the top. The color of these rocks when viewed from a distance is light greenish grey. The pale color was what prompted Dawson's original description for this series. The color is quite variable when individual outcrops are examined and range from light grey, grey, light green, brown to dark brown.

The sandstones of the Oldman formation show a great variation. They range in occurrence from soft, relatively uncemented sands which show little stratification to hard, massive, ledge forming sandstones. The harder ledges are due to the increase in calcareous matter which acts as a cement. Some of these hard ledges have been observed to grade laterally into soft uncemented sand. This suggests that some secondary cementation has occurred. Many of the harder sandstone ledges exhibit crossbedding while others are evenly bedded. Due to the variable character of the cementation, these sandstones weather locally into

somewhat castellated forms and lenticular masses.

The shales are usually light green in color and contain much argillaceous material. When wet they are quite plastic due to the contained clay. The weathering of these shales forms a light grey to white coating or wash on the outcrops. They tend to weather into a miniature badland type of topography but the surface coating is relatively impervious to moisture and this retards much of the erosion which would otherwise develop.

Lensing, ironstone bands are quite common, and where cavities and cracks have developed, they are often found to have well developed calcite crystals lining the cavities and cementing the breaks. Clay-ironstone nodules are relatively abundant and have also been observed with fractures recemented with calcite. The porous nature of much of the sandstones suggests recementation due to circulating ground water which deposits the calcite from solution.

The coal seams are confined to the uppermost part of the Oldman formation, and occur in the transition series between the continental Oldman formation and the marine Bearpaw formation. There is a change from the light colored, pale sandstones and shales of the typical Oldman beds upward into dark grey to brown, thinly

bedded sulfurous and gypsiferous, carbonaceous shales containing plant remains. Thin ironstone bands and concretions are common in these shales. The coal seams range in thickness from six inches to $4\frac{1}{2}$ feet. This latter figure refers to the "Lethbridge seam" which is mined extensively throughout the district. There is a variation in the thickness of the Lethbridge seam from 4 feet to as much as 7 feet, and a difference of 2 feet in thickness has been known to occur in the same mine. There is usually a thin shale break found in the seam, dividing it in two parts, the lowermost portion of the two usually being somewhat thicker than the upper. The shaly break or bone, ranges from 1" to 6" in thickness and so far as is known, is invariably present.

The coal is quite hard and on the outcrop has been more resistant to erosion than the surrounding soft shales. This results in a massive, prominent band formed by the main Lethbridge seam. It generally presents a smooth face due to the well developed cleavages. There are two directions of cleavage, one in a direction N50E and the other approximately at right angles in a direction N 40° W. These cleavages are used to advantage in mining operations. The main cleat or cleavage is always under one foot in width and

often may be a few inches. This condition makes the recovery of lump coal difficult.

The Oldman formation is not known to be entirely exposed anywhere on the southern plains, but a comprehensive section has been compiled from exposures along the Oldman river by Sproule, 1940, (54). He obtained a thickness of 378' of which he assigned the upper 84' to the Lethbridge Coal member. The Oldman-Bearpaw boundary was taken as the top of the uppermost bed of coal or carbonaceous shale. As pointed out by Sproule "this permits ready correlation of surface and well-log data". Sproule's lower boundary was drawn at the base of a massive, cross bedded sandstone, somewhat above the highest persistent carbonaceous bed of the Foremost type.

A cutbank on the west side of the river in the N.E.$\frac{1}{4}$ of section 35-8-22-4, exposed the following section:

Thickness	
	Unconsolidated deposits
20'	shale, dark, thinly bedded, sulfurous, containing scattered ironstone concretions
2"	ironstone
15'	shale silty, brown, chunky weathering, slightly sulfurous, gypsiferous, containing scattered ironstone concretions
Oldman formation	
1'	coal with a 2" _Ostrea_ bed above it.

9'	shale, rusty, carbonaceous, thinly bedded, sulfurous	
10"	thin ironstone bands	
2½'	shale, dark grey, thinly bedded	
8"	coal	
2½'	shale, dark grey thinly bedded	
2"	ironstone	
3'	shale, dark grey to black, carbonaceous, thinly bedded, sulfurous, rusty weathering.	
2½'	coal	Lethbridge coal seam
2"	shale	
2'	coal	
2'	shale, dark, carbonaceous, grades up into coal.	
5'	shale, light grey, thinly bedded, silty	
5"	ironstone	
3½'	shale, sandy, dark grey weathering	
3½'	shale, very carbonaceous, thin coaly stringers.	
	Base of section.	

This outcrop affords a good section of the Lethbridge coal seam and the associated beds above and below it. The Bearpaw-Oldman contact is placed above the highest carbonaceous bed, following the definition of Sproule.

The variable stratification of the Oldman formation makes its description difficult. There are no horizons which may be used for purposes of correlation with the possible exception of the coal seams which

occur in the upper part of the formation. The following section, exposed in the S.E.¼ of section 19-8-21-4, is typical of the Oldman formation.

Thickness	
	Unconsolidated deposits
1'	limestone band
20'	shale, grey green, silty
1½'	sandstone, hard, grey to rusty, fine grained, ferruginous
6'	sandstone, soft, light grey, fine grained
5'	sandy shale
1½'	sandstone, hard, grey, crossbedded, fine grained
5'	concealed
10"	sandstone, dark, well bedded, fine grained
15'	shale, grey green, chunky
18"	limestone band
5'	shale, grey, silty
1½'	sandstone, hard, fine grained, limey
4'	shale, light grey to greenish
2'	sandstone, light grey, fine grained, hard
6'	shale, light grey, silty
1'	ironstone
2'	sandstone, light grey
8"	limestone band
10'	sandstone, soft, light grey, contains much clay.

The base of the formation is not exposed in the area, but has been defined by Dowling, 1915, (25) as "a certain coal seam". This is the seam mined at Taber, the position of which is not definite except at that locality.

Sproule's thickness of 378' is somewhat thinner than the section penetrated in Keho #1. The thickness was determined to be 590' by an examination of the samples. It is known that the Oldman formation thickens from east to west. When this is considered, as well as the difficulty in compiling an accurate section from intermittant exposures, the discrepancy in these figures is not great.

Palaeontology

Many fresh and brackish water molluscs, as well as an imposing list of vertebrate remains have been described from the Oldman formation. In the Lethbridge district, oyster beds composed predominantly of Ostrea subtrigonalis shells occur in the coal series at the top of the formation. These beds range in thickness from 2" to 8'. In the Lethbridge Collieries mine in Sec. 30-10-21-4, the roof in a large part of the mine is composed of a bed of these shells. Faults show that it attains a thickness of 8', although its local extent is marked since it is known to be absent in other parts of the mine.

Many fragments of bone were observed in the strata of the Oldman formation, but were not complete enough to warrant collecting. Fragments of plant stems are also of common occurrence, but are of no diagnostic value as fossils.

Age

The Oldman and Foremost formations, together form a continental wedge between the marine shales of the contiguous Bearpaw and Pakowki shales. The Bearpaw has been assigned a Campanian age in the European section and the Pakowki is correlated with part of the Santonian. The intermediate position of the Oldman-Foremost formations makes them correlative of the upper part of the Santonian and lower Campanian.

Bearpaw Formation

Name

The Bearpaw formation was first named and described by T. W. Stanton and J. B. Hatcher in 1903,(64) from sections in the Bearpaw Mountains, Montana. Dowling, in 1917, (27) used the term Bearpaw in describing the shales of this formation in southern Alberta.

Distribution

The Bearpaw formation underlies the greatest part of the area. It occurs as a broad band trending approximately north-south across the area. The width of

outcrop is narrower at the southern boundary , becoming wider toward the north. This variation in the outcrop is due to the decrease in regional dip to the north, which is in turn a reflection of the decreasing plunge of the Sweetgrass anticline.

The Bearpaw shales are first exposed along the banks of the river in the region of the Monarch fault zone. They are involved in this disturbance along with the overlying Blood Reserve and St. Mary River formations, Intermittant exposures occur to the mouth of St. Mary River where they are in fault contact with the Oldman formation.

The Bearpaw is again exposed near the railway bridge at Lethbridge, as it dips downstream on the south-west limb of a gentle syncline. Occasional exposures occur on the sides of the valley to Section 6-10-21-4, where the Bearpaw formation is cut off by a fault. It is possible that some of the coulees, heading back to-wards the northwest in township 10-21-4 may expose some of the basal beds below the drift.

Lithology and Thickness

The Bearpaw formation is a marine series of steel grey, green grey, chocolate, fissile shales containing light grey, finely laminated sandstone members and sandy shales. Bentonite beds are common, and are light grey

to grey green in color. Lensing bands of ironstone occur as well as irregularly shaped concretionary masses up to 5' in diameter. Smaller nodules up to 6" in diameter are common and often contain fossils.

T. A. Link and A. J. Childerhose, 1931, (58) described a number of lithologic units which may be recognized. The lower one third of the Bearpaw is predominantly dark grey, marine shale. The uppermost two thirds contains three sandy zones. The Bearpaw is about 730' thick.

The lowermost sandstone member they named the *Magrath sandstone*. It is 62' thick and occurs 210' above the base. It contains abundant *Arctica ovata* shells. The *Kipp sandstone* occurs 370' above the base and has a thickness of 40'. *Placenticeras meeki* and *Baculites ovatus* occur in profusion above and below it. A thin glauconitic sandstone bed occurs 30' above it. The *Ryegrass member* occurs 84' below the top of the Bearpaw. It has a thickness of at least 90' and its separated by its bluish coloration.

The following table illustrates the stratigraphic position of the various members of the Bearpaw formation:

Bearpaw Formation 730'	Shale	84'
	Ryegrass member	90'
	Shale	146'
	Kipp member	40'
	Shale	98'
	Magrath member	62'
	Shale	210'

Downstream from Lethbridge, outcrops of Bearpaw may be found on both sides of the river. These consist of dark grey, rusty weathering fissile shales containing limestone nodules and limey bands. Thin bentonite bands may also be observed in the exposures. *Baculites ovatus*, *Gervillia recta var. borealis* were collected from these shales. In lsd. 15, Sec. 24, Tp. 9, R.22, W.4th, the following section is exposed:

Thickness	
	Saskatchewan Gravels
22'	sandy shale, thinly bedded, rusty weathering, gypsiferous. Contains scattered ironstone lenses.. Shale forms small spherical mud-balls.
6'	silty sandstone and shale, light grey, rusty weathering. Contains limey bands which are fossiliferous - *Arctica ovata*, *Arctica ovatavar. alta*, *Placenticeras placenta var. ontercalare*.
11'	shale,.dark sandy, chunky weathering, containing stringers and pockets of buff sand - grades into higher sandy bed - contains poorly preserved *Arctica*

10'	shaly sandstone, dark, light grey weathering, bedded, contains *Arctica*
3"	lenticular ironstone, composed of *Arctica* shells
27½'	sandy shale, dark grey, light grey weathering, bedded, containing poorly preserved shells
5"	sandy limestone band, composed predominantly of *Arctica* shells
13'	shaly sandstone, dark grey, poorly bedded, contains discoidal, sandy, limestone concretions, up to 1½' in diameter. Scattered *Arctica* shells occur in these beds.
7½'	sandy shale, dark grey, rusty weathering, chunky, gypsiferous.
	Covered interval for 27' to river level.

These beds are considered to correspond to the lower part of the Magrath sandstone (Arctica zone) of Link and Childerhose (38). A bore hole located in the N½ of Section 24-9-22-4 encountered the main Lethbridge coal seam at a depth of 226'. It was spudded in beds of the lower part of the above section. At Lethbridge the Bearpaw-Oldman contact was drawn 20' above the main seam. The lower part of the above section is thus about 200' above the base of the Bearpaw. By definition the Magrath sandstone is 210' above the base of the Bearpaw formation. This outcrop is very close to the axis of the syncline. Downstream, the dark grey, fissile shales of the lower part of the Bearpaw are exposed on the rising northeast limb.

Palaeontology

The Bearpaw formation contains a well known fauna. The following forms were collected by the writer:

Placenticeras placenta var. intercalare

Arctica ovata

Arctica ovata var. alta

Gervillia borealis

Baculites compressus

Gastropod

Sphaerium

Age

The Bearpaw is correlated with the Campanian of Europe on the basis of *Inoceramus barabini* by R.J.W. Douglas, 1942, (21) Landes makes the same correlation on the basis of *Baculites compressus* and *Acanthoscaphites nodosus* which are abundant in the Bearpaw. (54)

Blood Reserve Formation

Name

The formation was named by Russell in 1931. (51) The sandstones of the Blood Reserve had previously been correlated with the Fox Hills formation of Montana. Russell considers it to be, at least in part, older than the Fox Hills formation.

Distribution and Thickness

The Blood Reserve formation occurs as a narrow

band trending northwards on the western side of the area. The width of outcrop varies from south to north, due to the northward thinning of the formation. Russell refers to a section exposed in Section 26-8-23-4 where the thickness was determined at 77'. The thickness near Monarch is 40'.

The location of the Blood Reserve formation along the eastern edge of the Blood Indian Reserve as shown on the Geological Map (Encl.#1) has been obtained from the work of Russell. (51)

Lithology

The Blood Reserve formation consists predominantly of massive, fine to medium grained, grey to buff weathering sandstone with a calcareous matrix. Where well exposed it weathers in to castellated and large mushroom forms. Local thin shale members are present.

A section, exposed near Monarch in the N.W.¼ of section 31-9-23-4 is as follows:

Thickness	
12'	shale, dark brown, sandy
35'	sandstone, grey, massive, buff to rusty weathering, calcareous
5'	shale, dark grey, carbonaceous, sandy

The Blood Reserve formation is not exposed north of Monarch due to the thickness of the glacial deposits.

The contacts with the contiguous Bearpaw and St. Mary River formations are gradational. The dark, blue grey shales of the Bearpaw grade upward into the silty, carbonaceous shales of the lower part of the Blood Reserve formation. The contact is taken at the first appearance of the carbonaceous shale.

Russell, 1931, (51) takes the upper contact at the top of the massive sandstone which is the main unit of the Blood Reserve formation. This places the overlying dark shales, containing a brackish water fauna of Ostrea glabra and Corbula perangulata in the basal part of the St. Mary River formation.

Age

Baculites compressus has been collected from the Blood Reserve sandstone which is correlated with the fauna of the Campanian of Europe. (54).

St. Mary River Formation

Name

The term "St. Mary River" was applied to sandstones and shales occurring above the Fox Hills sandstone and below the beds of the Willow Creek formation by Dawson in 1884. (18) This nomenclature has been retained for the southern plains.

Distribution

The St. Mary River beds are the youngest strata outcropping in the Lethbridge district. They underlie the westernmost part of the area and occupy a band trending north-south.

Lithology and Thickness

No detailed study of this formation was made and only the lower part occurs within the Lethbridge district. Exposures of these beds occur on the Oldman river above Monarch.

Russell, 1931, (51) measured 66' of St. Mary River beds at the Monarch fault zone. These are predominantly light grey sandstones, in part massive weathering. Thin dark shale bands are present and oyster beds form coquinas up to 3' in thickness in the lower part.

Age

The age of the St. Mary river formation is not based on faunal evidence. Its stratigraphic position suggests a correlation with part of the Maestrichtian of Europe (P.S.Warren - personal communication).

Cenozoic Era

Tertiary Period

Pliocene ?

Saskatchewan Gravels

Name

The Saskatchewan gravels were described by Dawson,

1884 (18) and named the South Saskatchewan gravels by McConnell in 1885 (41). The name has since been shortened to Saskatchewan Gravels in general usage.

Distribution

These gravels occur below the boulder till and above the bedrock. They are well exposed at Lethbridge and several other exposures were noted along the river below Lethbridge. No gravel deposits were observed along the river above the city of Lethbridge. They were observed lying immediately above the Lethbridge coal seam of the Oldman formation at Lethbridge and downstream lying immediately above strata of the Bearpaw formation.

Description of Gravels

The gravels consist of boulders and pebbles of quartzite, argillite, chert, conglomerate, sandstone, feldspar porphyry and basalt. The quartzite pebbles are most abundant, with a large percentage of argillites and sandstones. The conglomerates, feldspar porphyrys and basalts are the least abundant constituents. The thickness of these gravels averages 15' to 20'. The individuals show varying degrees of roundness but on the whole are well worn. The deposits are not well sorted, although roughly the larger constituents are more commonly towards the lower part. The size of the

constituents varies from sand up to cobbles 6" - 8" in diameter.

Description of Constituents

The quartzites occur in a variety of colors, from white to green to pink while the sandstones are generally buff in color. The argillites are also found to occur in a variety of colors from dark grey, to olive green to maroon. The porphyry is light grey to pink while the basalt is dull grey or dark green.

The quartzites, basalts, chert, sandstones and conglomerates are usually rounded and assume spherical to spheroidal shapes. The argillites are commonly disc shaped or flattened. The porphyritic pebbles are usually more angular, possibly due to the abundant phenocrysts of feldspar which would be more readily broken rather than rounded during transport.

The conglomerate is composed of pebbles of dark grey, to black, chert, cemented in a siliceous matrix. The basalt is amygdaloidal, with the amygdules containing quartz and some calcite. The porphyry contains large phenocrysts of orthoclase feldspar and other light colored crystals which are smaller in size.

Origin of Constituents

The quartzites, argillites and sandstones, as well as the basalt, are similar to strata of the pre-Cambrian

Lewis series, exposed near Waterton.

R. A. Daly, 1912, (14) refers to the red quartzites of the Grinnell formation and other strata of the Lewis series containing sandstones and quartzites. The Appekunny, Grinnell and Kintla formations contain great thicknesses of red and green argillites and metargillites similar to those of the Saskatchewan gravels. The Purcell lava and other flows originated from the same basaltic magma. Daly states "the vesicles are generally completely filled with crystallized calcite, less often with granular or radially arranged quartz and a few with both calcite and quartz". The vesicles in the basalt of the Saskatchewan gravels are filled with quartz and some calcite. It seems probable that these pre-Cambrian formations have been the source beds of part of the material in these deposits.

The chert pebbles are similar to cherty material contained in some of the Palaeozoic strata to the west. The limestones would not stand the transportation and are not represented in the deposits at Lethbridge. Dawson found limestone in these beds nearer the mountains.

The conglomerates of the lower Cretaceous of the foothills and mountains contain cherty pebbles similar to those of the conglomerate boulders in the Saskatchewan gravels. Volcanics in the upper part of the lower

Cretaceous produce porphyries similar to those of the gravels at Lethbridge. Both contain abundant, fresh crystals of orthoclase feldspar as a main constituent.

There seems to be little doubt as to the western origin of the constituents of the Saskatchewan gravels. R.L. Rutherford (56, 1937) described similar deposits in central Alberta. Referring to the main constituents of the gravels he states "Thus these three constituents all seem to have come from the west, presumably from beds in the Rocky Mountains."

It seems unlikely that the Saskatchewan gravels have been brought directly from the mountains during one cycle of erosion, transportation and deposition. The constituents of the gravels are quite hard yet for the most part, well rounded. Remnants of older Tertiary conglomerates occur elsewhere on the southern plains. Quartzite gravels occur as remnants on top of the Cypress hills and on other high plateaux west of Calgary. These are remnants of earlier plains which have later been eroded. It seems likely that they have contributed material which has been reworked and incorporated into the younger Saskatchewan gravels. (R.L. Rutherford - personal communication). It would follow that these Saskatchewan gravels have been subjected to several cycles of erosion, which has resulted in the high degree

of rounding exhibited by the various constituents.

Age

The Saskatchewan gravels of the Lethbridge area occur between the overlying Pleistocene Keewatin glacial material and underlying Upper Cretaceous bedrock. It is not possible to date these gravels from their occurrence in the Lethbridge district, rather, they must be considered in relation to the known Tertiary history of the whole southern plains.

P.S. Warren (69, 1939) correlated three plateaux located west of Calgary, with the Flaxville plain as developed in the foothills of Montana. The basis of this Correlation was the similarity in the quartzite gravels capping these plateaux with that of the Flaxville Plain in Montana. The accordance in the elevations relative to the front ranges of the mountains was also a factor in making this correlation.

To the east, the Hand Hills are considered to be a part of the Flaxville Plain, and are at a somewhat lower elevation than the hills west of Calgary. This plain had a gentle slope to the east. West of Calgary the elevation is about 4400', while the Hand Hills are 3500'. Milk River Ridge, south of Lethbridge, is considered to be too low in elevation to represent a remnant of this plain, Its elevation is 4100'-4300'.

The average elevation of the prairie level at Lethbridge is about 3100', with the Saskatchewan gravels exposed in the river valleys at 2800' approximately. The average level of the Flaxville Plain, were it represented at Lethbridge, would be about 4200'. The Saskatchewan gravels are at a considerably lower elevation than the calculated level of the Flaxville Plain.

A considerable period of erosion, prior to the advent of the Keewatin glaciers, must have occurred, to remove this thickness of material. The age of the Saskatchewan gravels must be post-Flaxville Plain and pre-Keewatin glaciation. The Flaxville gravels have been dated by J.W. Gidley (12) on the basis of fossils. He states that they are "not older than Miocene or younger than lower Pliocene".

The erosion of the Flaxville Plain occurred during late Miocene and early Pliocene. It is suggested that the Saskatchewan gravels in the Lethbridge district are late Pliocene in age.

Quaternary Period

Pleistocene Epoch

The Lethbridge area was glaciated by ice from the Keewatin centre to the northeast during Pleistocene time. These deposits have been described by many previous writers. Dawson (18, 1884) studied the glacial section

and recognized an upper and a lower part separated by "the remarkable sedimentary deposits" which he suggested were interglacial. Dawson and McConnell (19,1894) made later studies of the glacial deposits of Southwestern Alberta. Alden and Stebinger (1, 1913) examined the glacial section at Lethbridge and Dowling (27,1917) records two sections penetrated in bore holes, within the district. Allan (3, 1939) classified the glacial deposits of the Lethbridge area and Rutherford (56,1941) suggested post-glacial uplift to explain the high elevations of patches of Keewatin drift to the west. J. H. Bretz (7, 1943) attempted to correlate the Keewatin and moraines of central and southern Alberta.

Description of Glacial Deposits

Deposits of Keewatin drift immediately underlie the surface of the Lethbridge area. Good sections are exposed in the valley of the Oldman river. The drift lies above the Saskatchewan gravels and forms the major part of the High banks along the river.

The drift is separated into an upper and lower part by a band of silts. The upper till is grey in color and contains Keewatin boulders. The silts below it are light grey with thin dark bands. Scattered pebbles occur as thin lenses. The lower till is dark in color, in part due, to the ploughing up and inclusion

of considerable Bearpaw shale. Arctica ovata shells are abundant in parts of the drift. Quartzite boulders are common in the lower till, probably derived from Saskatchewan gravels in a similar manner.

The following section is exposed in the N.E.¼ of section 14-9-22-4:

Thickness	
100	Boulder till, grey to buff, compacted clays and sands containing boulders of granite, granite gneiss and quartzite.
20'	Silts, light grey to buff, compact, thin dark bands with lenses of pebbles.
35'	Boulder till, dark grey, compacted, sand and clay contains granite and granite gneiss and abundant quartzite boulders.
20'	Saskatchewan gravels.

Glacial History

The lower dark till marks the first advance of the Keewatin ice sheet in the Lethbridge district. This advance was followed by a withdrawal of the glacier with the formation of an interglacial deposit of silts. These silts seem to have been deposited in water, possibly small lakes which would be abundant, due to blockage of the main drainage by the retreating glacier. Small streams were active, but their competency was limited to the transport of small pebbles which were observed as lenses in the silts. Some of

silts may have accumulated by wind action, being deposited in the small bodies of water around the front of the ice sheet. There is no definite evidence to support this suggestion.

The interglacial period was terminated by a new advance of the glacier. It was during this time that the upper lighter colored till was deposited. Following the second advance, a series of lake deposits were formed as the glacier retreated. No study was made of these later silts but they were observed in road cuts, where the bedding is well illustrated.

Quaternary Period

Recent

Recent deposits of river silts are confined to the flood plain of the Oldman river. The floor of the valley contains abundant boulders, which have been derived by weathering of the glacial till. Saskatchewan gravels also supply some of these boulders.

CHAPTER IV

SUBSURFACE

The geological information which has been accumulated by the mining companies of the Lethbridge area, has never been published. These data consist of records of bore holes and mine shafts which have been carried to the main Lethbridge coal seam. This type of information is important, especially when numerous elevations are obtained on a marker horizon. These elevations may be used in the preparation of structural maps which in the case of the Lethbridge area, show the attitude of the coal measures throughout the district. The purpose of this section is to record all the available data on the coal seams of the Lethbridge field. The bore hole information will be tabulated separately from the data obtained in mining operations.

Exploratory Boring for Coal

The information, which was used in the preparation of the structural map of the Lethbridge coal seam (Encl.2) included the bore hole data. The locations, surface elevations, elevations of the coal, depths to the coal and available logs of these bore holes are set forth in the following tabulation. The information is arranged by townships from west to east, starting with township 8 and progressing north to township 11.

Bore Hole #1 Location - lsd 4 of sec. 28-8-22-4
Surface elevation 3,055'
Elevation of coal 2,705'
Depth of coal, 350'

#2 Location - S.E.¼ of sec. 27-8-22-4
Surface elevation 3,043'
Elevation of coal 2,753'
Depth to coal 290'

#3 Location - S.E.¼ of sec. 27-8-22-4
Surface elevation 3,045'
No coal.

#4 Location - N.W.¼ of sec. 27-8-22-4
Surface elevation 3,073'
Elevation of coal 2,763'
Depth to coal 310'

#5 Location - lsd 12 of sec. 27-8-22-4
Surface elevation 3,075'
Elevation of coal 2,746'
Depth to coal 329'

#6 Location - N.W.¼ of sec. 26-8-22-4
Surface elevation 3,030'
Elevation of coal 2,714'
Depth to coal 316'

#7 Location - lsd 16 of sec. 26-8-22-4
Surface elevation 3,010'
Elevation of coal 2,741'
Depth to coal 269'

#8 Location - lsd 16 of sec. 31-8-22-4
Surface elevation 2,805'
Elevation of coal 2,655
Depth to coal 150'

#9 Location - S.W. Corner of N.W.¼ of sec. 33-8-22-4
Surface elevation 3,041'
No Coal

#10 Location - S.W.¼ Corner of N.W.¼ of sec. 34-8-22-4
Surface elevation 3,060'
Elevation of coal 2,702'
Depth to coal 358'

Bore Hole #11	Location - lsd 13 of sec. 34-8-22-4	
	Surface elevation	3,060'
	Elevation of coal	2,669'
	Depth to coal	391'
#12	Location - lsd 13 of sec. 33-8-22-4	
	Surface elevation	3,045'
	Elevation of coal	2,662'
	Depth of coal	383'
#13	Location - lsd 16 of sec.34-8-22-4	
	Surface elevation	3,025'
	Elevation of coal	2,654'
	Depth to coal	371'
#14	Location - lsd 15 of sec. 35-8-22-4	
	Surface elevation	2,982'
	Elevation of coal	2,666'
	Depth to coal	316'
#15	Location - lsd 12 of sec. 3-9-22-4	
	Surface elevation	3,060'
	Elevation of coal	2,641'
	Depth to coal	419'
#16	Location - lsd 3 of sec. 2-9-22-4	
	Surface elevation	2,988'
	Elevation of coal	2,629'
	Depth to coal	359'
#17	Location - lsd 6 of sec. 2-9-22-4	
	Surface elevation	3,005'?
	Elevation of coal	2,613'
	Depth to coal	392'?
#18	Location - lsd 1 of sec. 7-9-22-4	
	Surface elevation	?
	Elevation of coal	2,598'
	Depth to coal	?
#19	Location - lsd 16 of sec. 7-9-22-4	
	Surface elevation	3,000'
	Elevation of coal	2,541'
	Depth to coal	459'
#20	Location - lsd 16 of sec.8-9-22-4	
	Surface elevation	3,058'
	Elevation of coal	2,522'
	Depth to coal	536'

Bore Hole #21	Location - S.W.corner of N.W.$\frac{1}{4}$ of sec. 10-9-22-4	
	Surface elevation	3,055'
	Elevation of coal	2,581'
	Depth to coal	474'
#22	Location - lsd 12 of sec.11-9-22-4	
	Surface elevation	3,002'
	Elevation of coal	2,566'
	Depth to coal	436'
#23	Location - lsd 1 of sec.10-9-22-4	
	Surface elevation	3,010'
	Elevation of coal	2,615'
	Depth to coal	395'
#24	Location - S.E.$\frac{1}{4}$ of sec. 11-9-22-4	
	Surface elevation	2,985'
	Elevation of coal	2,596'
	Depth to coal	389'
#25	Location lsd 16 of sec. 12-9-22-4	
	Surface elevation	2,709'
	Elevation of coal	2,606'
	Depth to coal	103'
#26	Location - S.W. corner of N.W.$\frac{1}{4}$ of sec. 7-9-21-4	
	Surface elevation	2,714'
	Elevation of coal	2,636'
	Depth to coal	78'
#27	Location - lsd 12 of sec. 17-9-22-4	
	Surface elevation	3,040'
	Elevation of coal	2,484'
	Depth of coal	556'
#28	Location - S.E. corner of N.E.$\frac{1}{4}$ of sec. 18-9-22-4	
	Surface elevation	3,030'
	Elevation of coal	2,521'
	Depth to coal	509'
#29	Location - lsd 5 of Sec. 15-9-22-4	
	Surface elevation	3,027'
	Elevation of coal	2,537'
	Depth to coal	490'
#30	Location - lsd 1 of sec.15-9-22-4	
	Surface elevation	3,015'
	Elevation of coal	2,560'
	Depth to coal	455'

Bore Hole		
#31	Location - N.E. corner of lsd 14 of sec. 15-9-22-4	
	Surface elevation	3,015'
	Elevation of coal	2,481'
	Depth to coal	534'
#32	Location - lsd 16 of sec. 14-9-22-4	
	Surface elevation	2,950'
	Elevation of coal	2,475'
	Depth to coal	475'
#33	Location - lsd 1 of sec. 14-9-22-4	
	Surface elevation	2,960'
	Elevation of coal	2,570'
	Depth to coal	390'
#34	Location - lsd 8 of sec. 13-9-22-4	
	Surface elevation	?
	Elevation of coal	2,540'
#35	Location - lsd 1 of sec. 18-9-21-4	
	Surface elevation	?
	Elevation of coal	2,599'
#36	Location - Centre of sec. 25-9-23-4	
	Surface elevation	2,864'
	Elevation of coal	2,349'
	Depth to coal	519'
#37	Location - lsd 1 of sec.35-9-23-4	
	Surface elevation	2,845'?
	Elevation of coal	2,250'?
	Depth to coal	595'?
#38	Location - lsd 16 of sec. 19-9-22-4	
	Surface elevation	?
	Elevation of coal	2,427'
#39	Location - lsd 1 of sec.20-9-22-4	
	Surface elevation	3,060'
	Elevation of coal	2,470'
	Depth to coal	590'
#40	Location - lsd 15 of sec.24-9-22-4	
	Surface elevation	2,658'
	Elevation of coal	2,431'
	Depth to coal	227'
#41	Location - S.E. corner of lsd 12 of sec. 24-9-22-4	
	Surface elevation	2,704'
	Elevation of coal	2,453'
	Depth to coal	251'

Bore Hole #42	Location - lsd 11 of sec. 19-9-21-4	
	Surface elevation	?
	Elevation of coal	2,516'
#43	Location - S.E. corner of lsd 6 of sec. 20-9-21-4	
	Surface elevation	?
	Elevation of coal	2,604'
#44	Location - lsd 3 of sec. 27-9-22-4	
	Surface Elevation	2,993'
	Elevation of coal	2,381'
	Depth to coal	612'
#45	Location - lsd 1 of sec. 30-9-21-4	
	Surface elevation	?
	Elevation of coal	2,572'
#46	Location - lsd 3 of sec. 31-9-22-4	
	Surface elevation	3,045'
	Elevation of coal	2,356'
	Depth to coal	689'
#47	Location - lsd 16 of sec. 30-9-22-4	
	Surface elevation	3,050'
	Elevation of coal	2,369'
	Depth to coal	681'
#48	Location - lsd 3 of sec.32-9-22-4	
	Surface elevation	3,052'
	Elevation of coal	2,382'
	Depth to coal	672'
#49	Location - lsd 1 of sec. 32-9-21-4	
	No coal	
#50	Location - lsd 10 of sec. 32-9-21-4	
	No coal	
#51	Location - lsd 13 of sec. 23-10-22-4	
	Surface elevation	3,035'
	Elevation of coal	2,497'
	Depth to coal	538'

Log of Bore Hole #51

3035'00" - ground level
2529'4" - log not available

Oldman Formation

2529'4" - shale
2518'1" - shale, coarse sandy
2516'7" - shale, carbonaceous
2515'4" - shale
2512'4" - sandstone, grey, fine grained
2512'2" - shale, carbonaceous
2511'10" - coal
2511'1" - shale, dark, carbonaceous
2509'4" - Shale, dark, grey, carbonaceous, some silty shale
2503'2" - ironstone
2502'9" - hard shale
2500'7" - ironstone
2500'6" - shale, dark, grey, carbonaceous
2497'3" - coaly bone
2497'0" - clean boal - Lethbridge seam
2493'5" - coaly bone
2491'8" - coal with 2" bands of dull coal
2490'10" - shale, black, coaly, carbonaceous
2489'4" - shale, black, coaly, carbonaceous
2487'5" - silty shale
2485'9" - shale, dark, grey, silty, carbonaceous
2485'2" - sandstone, thin, bedded grey
2484' 2" - shale, dark, grey, carbonaceous
2482'3" - coal
2482'2" - shale, black carbonaceous, silty, coaly
2480'10" - shale, grey, fine grained silty, carbonaceous
2478'10" - Total depth.

Bore Hole #52 Location - lsd 16 of sec. 23-10-22-4
Surface elevation 2,997'
Elevation of coal 2,644'
Depth to coal 353'

Log of Bore Hole #52

2997' ground elevation
2969'6" - log not available

Oldman Formation

2969'6" - shale, dark grey
2667'4" - siltstone, grey
2665'7" - shale, dark grey, soft, carbonaceous
2664'6" - sandstone, soft dark grey
2664' - coal and soft carbonaceous shale
2663'6" - shale, dark grey, slightly carbonaceous
2661' - siltstone, dark grey
2659'3" - ironstone
2658'9" - clean coal
2658'2" - shale, dark grey, carbonaceous
2656'3" - shale, dark grey silty
2653'6" - shale, dark grey carbonaceous
2650'9" - ironstone
2650'3" - shale, grey silty
2646'10" - dark shale
2646'6" - shale, black carbonaceous
2646' - shale, carbonaceous
2644'2" - shale, soft carbonaceous
2644' - clean coal)
2641'6" - bone)
2641'2" - clean coal)Lethbridge Seam
2640'2" - bone)
2639'8" - clean coal)
2637'5" - bone
2637'0" - clean coal
2636'6" - shale, black, coaly, carbonaceous
2634'8" - shale, dark grey, silty carbonaceous
2631'4" - shale, lighty grey, silty
2630'2" - ironstone
2629'8" - shale, dark grey, silty
2629'2" - sandstone, fine grained, dark grey
2628'9" - shale, coaly black
2628'3" - coal
2627'10" - no core
2625'4" - clean coal
2624'4" - shale, black, coaly, carbonaceous

2624'0" - clean coal
2625'10" - no core
2622'4" - shale, black coaly
2621'4" - shale, dark grey, silty
2620'4" - sandstone, dark grey, hard, cross bedded, fine grained
2619'4" - Total depth

#53 Location - N.E.¼ of sec.24-10-22-4
Surface elevation 2,982'
Elevation of coal 2,686'
Depth to coal 296'

#54 Location - lsd 1 of sec.24-10-22-4
Surface elevation ?
Elevation of coal 2,700'

#55 Location - S.E.¼ of sec.25-10-22-4
Surface elevation 2,939'
Elevation of coal 2,652'
Depth to coal 287'

#56 Location - lsd 1 of sec.30-10-21-4
Surface elevation 2,938'
Elevation of coal 2,735'
Depth to coal 203'

#57 Location - lsd 10 of sec.35-10-22-4
Surface elevation 3,004'
Elevation of coal 2,650'
Depth to coal 354'

Log of Bore Hole #57

3004' - surface elevation
2986' - clay
2984' - boulders
2979' - gravel
2976' - boulders
2970' - gravel
2967' - sand
2959' - hardpan
2944' - sand
2921' - clay
2917' - boulders
2914' - gravel
2894' - clay
2859' - clay and gravel
2853' - gravel

2849' - clay
2846' - hardpan
2834' - sand

Bearpaw Formation

2807' - shale, dark grey, bentonite
2781' - shale, dark grey
2761' - shale, dark grey, ironstone
2760'11" - bentonite
2726' - shale, dark grey
2725'11" - bentonite
2707' - shale, dark grey
2706'8" - bentonite, micaceous
2681' - shale, dark grey

Oldman Formation

2680' - sandy shale, dark grey, ferruginous
2671'6" - shale, dark grey
2670'6" - sandy shale, dark grey
2669'5" - coal
2668' - shale, carbonaceous, plants
2658' - shale, dark grey, scattered plants
2657'4" - shale, grey
2657' - coal
2656' - shale, dark, carbonaceous
2650' - coal, carbonaceous shale. Lethbridge seam
2647'6" - shale, grey, carbonaceous
2644' - shale, black, carbonaceous
2634' - coal, shaly coal
2628' - shale, sandstone, fine grained
2626' - sandstone, grey, fine grained
2623' - shale, sandy, grey
Total depth.

#58 Location - lsd 7 of sec. 36-10-22-4
Surface elevation 2,970'
Elevation of coal 2,655'
Depth to coal 315'

#59 Location - Centre of sec.31-10-21-4
Surface elevation 2,949'
Elevation of coal 2,653'
Depth to coal 296'

#60 Location - lsd 10 of sec.32-10-21-4
Surface elevation 2,941'
Elevation of coal 2,703'
Depth to coal 238'

Bore Hole #61 Location - lsd 1 of sec.32-10-21-4

Bore Hole #61	Location - lsd 1 of sec.32-10-21-4	
	Surface elevation	2,943'
	Elevation of coal	2,738'
	Depth to coal	205'
#62	Location - lsd 13 of sec.5-11-21-4	
	Surface elevation	3,011'
	Elevation of coal	2,617'
	Depth to coal	394'

Log of Bore Hole #62

3011'	- surface elevation
2998'	- clay
2991'	- boulders
2985'	- gravel
2957'	- clay, gravel and boulders
2921'	- clay
2897'	- sand
2868'	- clay
2846'	- clay, boulders and gravel
2841'	- boulders
2837'	- gravel
2829'	- sand
2821'	- clay
2818'	- gravel
2772'	- clay
2766'	- boulders
2718'	- clay and boulders
2716'	- gravel
2699	- clay
2689'	- clay and gravel
2647'	- shale, dark grey, bentonite

Oldman Formation

2646'	- shale, sandy, ferruginous
2642'	- oyster bed, Ostrea
2639'	- shale, dark grey
2637'6"	- sandstone, shaly
2637'	- coal
2635'	- shale, grey, carbonaceous
2630'	- shale, dark grey
2626'	- Ostrea bed
2623'3"	- coal
2622'6"	- shale, dark
2621'11"	- poor coal
2617'3"	- Lethbridge seam

2616'11" - shale
2615'9" - shale and bone
2613' - shale, coaly streaks
2611'9" - shale, coaly
2610'11" - shale, black, carbonaceous
2609'4" - shale, brown
2605' - shale, grey, olive grey
2598' - medium grained, grey, massive sandstone.
Total depth

Bore Hole #63 - Location - lsd 13 of sec.3-11-21-4
Surface elevation 2,990'
Elevation of coal 2,670'
Depth to coal 320'

Log of Bore Hole #63

2990' - surface elevation
2990' - clay
2975' - boulders
2974' - clay
2971' - clay
2935' - sand
2925' - gravel and boulders
2912' - clay
2905' - boulders
2904' - clay
2882' - sand
2850' - gravel and boulders
2842' - gravel
2817' - sand
2799' - clay and gravel
2773' - clay
2741' - gravel
2739' - sand and clay
2723' - sand
2710' - clay
2696' - boulders
2694' - clay
2687' - sand
2676' - clay

Oldman Formation

2670' - coal and bone. Lethbridge seam?
2666' - shale, black carbonaceous
2656' - shale, dark grey, plant remains
2655' - sandstone, grey, fine medium grained, plants
2649' - shale, sandy, olive to dark grey, carbonaceous

2647' - sandstone, shaly, dark grey, coaly
2646' - shale, dark grey, carbonaceous
2631' - shale, sandy, carbonaceous
2607' - sandstone, shaly, grey, medium fine grained, plants
2581' - sandstone, massive with fine cross-bedding, medium to fine grained
Total depth.

#64 Location - lsd 13 of sec. 1-11-21-4
Surface elevation 2,940'
Elevation of coal Lethbridge seam not present

Log of Bore Hole #64

2940' surface elevation
2940' - clay, sand and gravel
2880' - sand and gravel
2860' - clay
2840' - sandy clay
2812' - clay, small pockets of gravel
2780' - sand
2760' - clay, sand and gravel
2718' - sand and clay
2693' - small boulders and gravel
2690' - sand and clay
2675' - boulders
2674' - clay
2667' - clay and sand
2643' - boulders
2641' - clay
2637' - clay and gravel
2618' -

Oldman Formation

2618' - shale, light grey, sandy, ironstone
2615' - shale, grey to white bentonitic
2613'6" - sandstone, medium grained, light grey
2612'6" - shale, light grey, carbonaceous
2607'6" - shale, sandy, light grey
2605' - shale, grey to light grey
2602' - shale, dirty brown, carbonaceous, oysters
2600' - sandstone, shaly, drab, olive grey, carbonaceous, oysters
2593' - shale, sandy, light grey, green
2589' - shale, grey green
2588' - sandstone, green to light grey, fine to medium grained, massive.
Total depth

The drill passed from the drift into beds of the Oldman formation below the Lethbridge seam. Erosion has removed the upper part of the Oldman formation including the Lethbridge seam.

Bore Hole #65	Location - Centre of	sec.15-11-22-4
	Surface elevation	3,180'
	Elevation of coal	2,410'
	Depth to coal	770'
#66	Location - lsd 16 of	sec.15-11-22-4
	Surface elevation	3,192'
	Elevation of coal	2,432'
	Depth to coal	760'
#67	Location - lsd 4 of	sec.25-11-22-4
	Surface elevation	3,120'
	Elevation of coal	2,520'
	Depth to coal	600'

Coal Mines of the Lethbridge Coal Field

Many of the elevations of the coal, used in the preparation of the structural map of the Lethbridge coal field, were obtained from mine plans, where established elevations are known. Earlier plans do not carry true elevations as it was not necessary at that time to "tie in" to Government bench marks. The mines are tabulated under two headings - "Operating Mines" and "Abandoned Mines".

The mines are listed in order of "Mine Number". Each new mine, which is opened in the Province, is assigned a "Mine Number" by the Mines Branch of the

Province of Alberta. Surface elevations, elevations of the coal, depth of overburden, sections of the coal and logs of mine shafts are included where ever possible. The Lethbridge seam is the only commercial seam, and references to the coal will be understood to mean the Lethbridge coal seam.

Rank of the Lethbridge Coal

E. Stansfield and W.A. Lang (63, 1944) have published typical analyses for each of the coal areas of Alberta. These coal areas are those which were set forth by J.A. Allan in 1940 (4, Map #18). According to the Canadian classification, the coal, mined from the Lethbridge seam, is High Volatile C Bituminous. This is a higher rank than the average "Belly River" coal of the plains and proximity to the centre of deformation to the west is believed to be the contributing factor for this variation.

Typical Analysis of Lethbridge Coal

Proximate		Ultimate(with 11.7% moisture)	
Moisture	%11.7	Carbon...........	% 61.3
Ash.............	% 9.7	Hydrogen.........	% 5.5
Volatile matter	%33.6	Sulphur..........	% 0.6
Fixed carbon....	%45.0	Nitrogen.........	% 1.5
		Oxygen...........	% 21.4
		Ash..............	% 9.7

Fuel ratio (FC/VM), 1.35

Calorific value, gross, in B.t.u. per lb., 10,680

The net calorific value of this coal is approximately 500 B.t.u. per lb. lower than the gross value.

Abandoned Mines

Much of the information regarding the earlier mines has been obtained from the Annual Reports of the Mines Branch (78).

Mine #3 Canadian Pacific Railway Company, Department of Natural Resources.

Two mines Galt #3 and Galt #6, operated on the same property under the same mine number.

Galt #3

Location - lsd 13-6-9-21-4

Opened - 1895 Abandoned - March 1924

Surface elevation - 2962'

Elevation of Coal - 2672'

Depth of Coal - 290'

Details of seam

0' 10" slate
1' 6" coal
0' 2" shale
2' 8" coal
1' 0" bone

Galt #6

Location - lsd 15-18-9-21-4

Opened - 1908 Abandoned - April 1935

Surface Elevation - 2950 '

Elevation of coal - 2571'

Depth to coal - 379'

Log of Air Shaft - Galt #6

2950' - surface elevation
2950' - gumbo, clay and sand
2724' 2" - gravel
2705' 2" - shale
2686' 2" - fireclay
2686' - shale
2621' 2" - ironstone
2620' 8" - shale
2613' 3" - ironstone
2612'11" - shale
2596' 4" - mussel bed
2595' 1" - coal
2594' 9" - shale, black
2593' 8" - coal
2591'11" - shale, black
2591' 8" - shale
2580'11" - ironstone
2580' 8" - shale
2578' 1" - coal
2577' 8" - shale
2575' 1" - ironstone
2574' 7" - shale
2573' 7" - coal
2572'11" - shale
2571' - coal)
2570'10" - shale) Lethbridge seam
2568' 5" - coal)
2567' 7" - shale, black
total depth

Details of seam (5 sections)

shale					
coal	1' 6"	1'6½"	1' 6"	1' 7"	1' 3"
bone	1½"	3"	3"	1½"	1"
coal	2' 7"	2' 4"	2' 3"	2'3½"	2' 5"
shale					

Mine #54 Federal Coals Limited

Location - lsd 5-36-8-22-4

Opened - 1902. Abandoned - March 1924

The coal was mined from the outcrop along the Oldman river.

Elevation of the coal - 2729'

Details of seam (2 sections)

shale		
coal	1' 8"	1' 7"
bone	1½"	2"
coal	2'10"	2'5½"
shale		

Mine #92 William Barnes

Location - lsd 8-31-9-21-4

Opened - 1902 Abandoned - January 1922

Mine #104 Consolidated Diamond Collieries Limited

Location - lsd 6-6-10-21-4

Opened - 1905 Abandoned - February 1930

Entry on outcrop along the Oldman river

Elevation of coal at outcrop - 2677'

A bore hole was drilled in lsd 6-6-10-21-4

Surface elevation - 2969'

Elevation of coal - 2708'

Depth to coal - 261'

Details of seam

shale	
coal	1'9½"
shale	1½"
coal	2' 7"
shale	

Mine #174 Lethbridge Collieries Limited

Location - lsd - 2-21-9-22-4

Opened - 1911 Abandoned - April 1936

Opened by N.C. Pitcher

Surface Elevation - 3042'

Elevation of coal - 2487'

Depth to coal - 555'

Log of Shaft - Mine #174

3042' - surface elevation
3042' - sandy clay
3026' - gumbo, brown
2967' - clay, blue sandy
2914' - clay, white sandy
2864' - sand
2850' - boulders
2832' - sand
2807' - gumbo, blue
2796'6" - Saskatchewan Gravels??
2770'6" - shale
2625' - shale, dark blue
2621' - shale
2608' - shale
2594' - shale, dark blue
2587' - shale, dark
2511'2" - coal
2510'6" - shale, dark
2508'4" - coal
2507'6" - shale, blue
2491' - ironstone
2490' - shale, black
2487'3" - slate
2487' - coal Lethbridge seam
2482'9" - bone
2482'3" - coal
2481'9" - shale
total depth

Details of seam

shale	-
coal	1'6"
clay	½"
coal	2'3"
clay	3"
coal	9"
shale	

Mine #192 City of Lethbridge

Location - lsd - 7-36-8-22-4

Opened - 1909 Abandoned - September 1941

In lsd -9 - Saskatchewan Gravels form the roof and no top coal is present.

Details of seam

Saskatchewan Gravel	
coal	2'
clay	2"
coal	4'2"
shale	

Mine #195 Standard Lethbridge Collieries Limited

Location - lsd - 1,2,7,8,-28-9-21-4

Opened - 1909 Abandoned - 1911

No coal

Mine #203 New Barnes Mine Company

Location - lsd -9-31-9-21-4

Opened - 1909 Abandoned - December 1942

Depth of cover - 60'

Details of seam

coal	7"
shale	1'4"
coal	1'4"
clay	2"
coal	2'
shale	

Mine #217 Alex McWilliams

Location - Section 8-10-22-4

Opened - 1909 Abandoned - 1911

Mine #223 Adams Coal Mine Company Limited

Location - S.E.¼ of 16-10-21-4

Opened - 1910 Abandoned - 1913

Mine #225 John Thomas

Location - lsd 12 and 13-9-10-21-4

Opened - 1910 Abandoned - 1913

Mine #247 Chinook Coal Company

Location - lsd 7-12-10-22-4

Opened - 1910 Abandoned - 1925

Surface Elevation - 3007'

Elevation of coal - 2569'

Depth to coal - 438'

Details of seam

coal	1'½"
shale	4"
bone	1"
coal	1'8"
clay	2"
coal	2'6"
bone	

Mine #254 George Heighes

Location - Section 27-10-21-4

Opened - 1910 Abandoned - 1914

Mine #276 Diamond Sunrise Coal Company

Location - lsd 13-9-10-21-4

Opened - 1913 Abandoned - March 1924

Surface Elevation - ?

Log of strata at Mine #276

90'	Clay and gravel	
30'	shale	
4"	bone	
1'6"	coal	)
1'	bone	) Lethbridge seam
1'	coal	)
	shale	

Mine #343 A. J. McGuire

Location - E½ of Section 25-8-22-4

Opened - 1912 Abandoned 1913

Mine #372 Bathurst Coal Company Limited

Location - Section 5-10-21-4

Opened - 1912 Abandoned 1915

Mine #395 Michael Malloy

Location - lsd 15-27-10-21-4

Opened 1918 Abandoned November 1930

Surface elevation ?

Thickness of cover 182'

Thickness of seam 3'3"

Log of strata at Mine #395

30'	gravel and sand	
118'	shale	
4"	coal	
30'	shale	
6"	coal	
4'	shale	
3'3"	coal	Lethbridge seam
15'	shale	
8"	coal	
	shale	

Mine #411 Samuel Pyrah

Location - Section 8-8-21-4

Opened - 1913 Abandoned - 1914

No Coal

Mine #446 Alfred Riffell

Location - S.E.¼ of Section 31-9-21-4

Opened - 1914 Abandoned - 1914

Mine # 605 Christopher S. Donaldson

Location - N.W.¼ of Section 16-10-21-4

Opened - 1915 Abandoned - April 1916

Thickness of cover 145'

Thickness of seam 4'

Mine #636 Stephen Harrison

Location - N.W.¼ of Section 16-10-21-4

Opened and abandoned - 1916

Mine #674 Gerhard Erickson

Location - lsd 4-16-10-21-4

Opened - 1916 Abandoned - 1918

Mine #676 Lethbridge Coal Company Limited

Location - lsd.12-12-9-22-4

Opened - 1916 Abandoned - 1925

Surface elevation 2725'

Elevation of coal 2641'

Depth to coal 84'

Thickness of coal is 4'4"

Mine #713 Federal Coal Company Limited

Location - lsd 15-36-8-22-4

Opened - November 1917 Abandoned March 1928

Mine #733 Albert Firth and Company

Location - lsd 4-11-22-4

Opened - February 1918 Abandoned 1919

Mine #738 George Rollingson

Location - lsd 2-11-8-22-4

Opened - 1918 Abandoned ?

Surface elevation ?

Thickness of cover 50'

Thickness of coal 3'

Details of seam:

4"	coal
10"	bone
1' 10"	coal
10"	shale

Mine #750 John Noble

Location - lsd 13-27-10-21-4

Opened - July 1918 Abandoned - May 1937

Elevation of coal 2758'

Details of seam:

	shale
6"	poor coal
3'0"	coal
	shale

Mine #759 G. G. Hannah

Location - S.E.¼ of lsd 2-17-10-21-4

Opened - July 1918 Abandoned 1921

Mine #761 Southern Alberta Coal Company Limited

Location - lsd 4-36-8-22-4

Opened - July 1918 Abandoned- Nov.1923

Surface elevation ?

Thickness of cover 200'

Thickness of seam 4'

Mine #821 McNab Coal Company

Location - lsd 10-36-8-22-4

Opened - August 1919 Abandoned Nov. 1926

Mine #871 J. F. Hamilton

Location - lsd 14-36-8-22-4

Opened - November 1920 Abandoned 1940

Surface Elevation ?

Thickness of cover 30' - 200'

Thickness of seam 3'10"

Details of seam:

	shale
1'10"	coal
2"	bone
2' 2"	coal
	shale

Mine #889 Edward A. Wocknitz

Location - lsd 16-2-8-22-4

Opened - January 1921 Abandoned Feb.1935

Surface Elevation ?

Thickness of cover 30'

Thickness of seam 3'8"

Details of seam:

	shale
1'	bone
2'8"	coal
	shale

Mine #893 Hugh Evans

Location - lsd 1-16-10-21-4

Opened and abandoned 1921

No Coal

Mine #942 J. F. Van Brocklin and Phillip Wonski

Location - lsd 2-16-10-21-4

Opened - November 1921 Abandoned 1923

Mine #977 George Rollingson

Location - lsd 2-11-8-22-4

Opened and abandoned - 1922

Mine #983 E. H. F. Warren

Location - lsd 11-27-10-21-4

Opened - February 1922 Abandoned 1941

Surface elevation ?

Thickness of cover 75' - 200'

Thickness of seam 3'2"

Mine #988 North Lethbridge Coal Company

Location - lsd 16-31-9-21-4

Opened - April 1922 Abandoned March 1924

Elevation of coal 2769'

Details of seam:

	shale
1'5"	coal
3"	shale
2'8"	coal
	shale

Mine #992 Donaldson Coal Company

Location - lsd 16-36-8-22-4

Opened and abandoned - 1922

Mine #993 George Bourne

Location - lsd 5-11-8-22-4

Opened - May 1, 1922 Abandoned June 1925

Thickness of cover 34'

Thickness of seam 2'

Details of seam:

	shale
2'5"	coal
	shale

Mine #1045 A. Bembridge

Location - lsd 15-2-8-22-4

Opened - October 1922 Abandoned - 1942

Thickness of cover 150'

Thickness of seam 2'6"

Mine #1092 Central Coal Company of Lethbridge, Ltd.

Location - lsd 12-24-9-22-4

Opened - April 1923 Abandoned May 1926

Thickness of cover 250'

Thickness of coal 4'

Mine #1109 George Hamilton

Location - lsd 8-31-9-21-4

Opened - November 1923 Abandoned Nov.1942

Elevation of coal 2731'

Thickness of cover 75'

Thickness of coal 4'

Details of seam - two sections

shale		
coal	1'6½"	1'6"
clay	5"	2"
coal	1'11"	2'8"
shale		

Mine #1110 George Hamilton

Location - lsd 2- 1-9-22-4

Opened - November 1923 Abandoned 1927 .

Thickness of cover 100'

Thickness of seam 4'2"

Mine #1150 George Bourne

Location - lsd 5-11-8-22-4

Opened - May 1924 Abandoned October 1925

Thickness of coal 2'3"

Mine #1219 New Royal View Mine

Location - lsd 12-29-9-21-4

Opened - 1925 Abandoned 1945

Elevation of coal 2634'

Thickness of cover 250'

Thickness of seam 4'

Mine #1339 William Reece and Son

Location - lsd 12-16-10-21-4

Opened - November 1930 Abandoned July 1932

Details of seam:

	shale
1'10"	coal
8"	clay
2'6"	coal
1'	shale
10"	coal
	shale

Mine #1414 Picture Butte Coal Company

Location - lsd 13-34-10-21-4

Opened - April 1933 Abandoned March 1937

Thickness of cover 240'

Mine #1423 Brearley, Bateman and Blasco

Location - S.W.¼ of section 1-9-22-4

Opened - July 1933 Abandoned July 1939

Mine #1576 Kerralta Coal Company

Location - lsd 13-12-9-22-4

Opened - March 1941 Abandoned Feb.1944

Elevation of coal 2570'

Surface elevation 2960'

Depth to coal 390'

Thickness of seam 4'2"

Details of seam:

	shale
1'8"	coal
2"	clay
2'4"	coal
	shale

Mine #1577 J. J. Hamilton Coal Co. Limited

Location - lsd 2-17-10-21-4

Opened - March 1941 Abandoned Sept.1941

Surface elevation 2821'

Elevation of coal 2785'

Depth to coal 36'

Operating Mines

Mine #1095 J. C. Chester

Location - lsd 9-20-9-21-4

Opened - 1923

Surface elevation 2960'

Elevation of coal 2665'

Depth to coal 295'

Details of seam: (two sections)

shale		
coal	1'4½"	1'2"
clay	2½"	1"
coal	2'	2'5"
shale		

Mine #1263 Lethbridge Collieries Limited

Location - lsd 11-30-10-21-4

Opened - 1927

Surface elevation 2921'

Elevation of coal 2658'

Depth to coal 263'

Details of seam (four sections)

shale				
coal	2'1"	2'3"	3'6"	2'3"
clay	10"	8½"	2"	8½"
coal	2'9"	2'7½"	1'2½"	2'7½"
clay	6"	11"	8½"	11"
coal	8"	1'	10"	1'
shale				

Mine #1464 Lethbridge Collieries Limited

Location - lsd 3-2-9-22-4

Opened - 1934

Surface elevation 2988'

Elevation of coal 2633'

Depth to coal 355'

Details of seam (two sections)

shale		
coal	1'7½"	1'7½"
clay	3"	4½"
coal	2'5"	2'4"
shale		

Mine #1581 J. J. Hamilton

Location - lsd 11-24-9-22-4

Opened - 1941

Surface elevation 2675'

Elevation of coal 2448'

Depth to coal 227'

Details of seam (two sections)

coal	10"	
shale	1'	
coal	1'6"	1'7"
clay	2"	4"
coal	2'6"	2'2"
shale		

Exploratory Boring for Oil

The wells which are listed in the following tabulation have been used in the preparation of three regional structure maps (Encl. 4,5,6). This list includes all the wells within the area defined as townships 2 to 14, ranges 14 to 24, West of 4th Meridian, on which subsurface information is available. The horizons on which the maps are contoured do not outcrop on the southern plains of Alberta, which has necessitated referring to information gained by deep drilling.

The wells are listed by districts (following the Conservation Board) from west to east, starting in the southwest corner. The name, location, surface and subsurface elevations are included. These elevations all refer to sea level. Since some of the elevations are below sea level, plus and minus signs are used. Plus signs refer to elevations above sea level and minus signs refer to elevations below sea level.

Name of Well	Location	Surface elevation	Top of Alberta formation	Top of Lower Cretaceous	Top of Palaeozoic
Del Bonita - Twin River District					
Twin River 3	Lsd 9-10-2-20-4	4078	+2638?	+908	100
Twin River 2	Lsd 12-2-2-20-4	4028	+2648	+858	128
Twin River 2	Lsd 12-2-2-20-4	4028	+2618	+928	114
Ross Lake Province 1	Lsd 4-17-2-22-4	4433	+1353	-472	-1392
Red Coulee District					
Dalco R.C.2	Lsd 7-19-2-17-4	3630	+2980		540
B.A. #1	Lsd 8-30-2-16-4	3467	+2837	+1117	507
Spring Coulee District					
Spring Coulee 1,	Lsd 11-15-4-23-4	3737		-1230	-2198
Cord #1	Lsd 16-35-3-23-4	4049		-1031	-1941
Blood Indian Reserve 1	Lsd 10-31-5-23-4	3658	+178	-1702	-2609
Lyons-McIntyre 1	Lsd 14-19-3-21-4	3860	+1490	+280	-1190
Northwest West #1	Lsd 3-20-5-23-4	3679	+369		-2439
Warner District					
Gas Prod. & Trans. #1	Lsd 14-21-4-18-4	3414	+2444	+674	-14
Lethbridge District					
Monarch #2	Lsd 10-1-10-24-4	2945	+418		

Name of Well	Location	Surface elevation	Top of Albert formation	Top of Lower Cretaceous	Top of Palaeozoic
Keho #1	Lsd 2-17-11-22-4	3266	+ 966	-954	-1648
Raymond 1	Lsd 7-16-6-20-4	3132	+1712	- 18	- 783
Tempest 1	Lsd 4-27-9-19-4	2812	+1582	-118	- 728
Lethbridge Breweries 1	Lsd 16-36-8-22-4	2948	+1208		
Northwest 1	Lsd 14-22-8-22-4	3077	+1227	-658	-1474
Lethbridge Pet. & Ref.1	Lsd 12-11-8-22-4	2772	+1232	-528	-1372
Lethbridge south 1	Lsd 8-1-8-21-4	3021		-219	-934
Northwest Treaty 1	Lsd 4-17-8-23-4	3364	+ 194	-1586	-2667
Conrad-Skiff District					
Conrad Province 1	Lsd 8-11-5-15-4	3038	+2298	+ 628	+ 6
Conrad Province 2	Lsd 1-5-6-15-4	2960	+2240	+620	- 12
Conrad 55-5-A	Lsd 11-5-6-15-4	3040	+2170	+ 610	- 69
Conrad 55-21-B	Lsd 11-21-5-15-4	3094	+2264	+549	- 64
Conrad 55-33-B	Lsd 11-33-5-15-4	3077	+2217	+557	- 19
Conrad 77-33-B	Lsd 13-33-5-15-4	3070	+2200	+550	

Name of Well	Location	Surface elevation	Top - Alberta formation	Top - Lower Cretaceous	Top of Palaeozoic
Crow Indian Lake #2	Lsd 1-20-4-14-4	3082	+2382	+772	+126
Dauntless 1	Lsd 9-36-6-15-4	3019	+2197	+369	-269
Devonish 1	Lsd 5-27-5-14-4	3015	+2245		-125
Devonish 2	Lsd 11-11-5-14-4	2906		+541	+6
Devonish 3	Lsd 4-27-5-14-4	3008	+2235		
Devonish 4	Lsd 13-29-5-14-4	3034		+476	-106
Midcontinent 2	Lsd 14-24-6-15-4	3068	+2078	+423	-153
Wrentham 1	Lsd 11-2-6-17-4	3127	+2147	+422	-145
Taber District					
Cole Hunter 1	Lsd 3-11-10-17-4	2597	+1777	-103	-740
C.W.N.G.L.H. & P. Co. 1	Lsd 14-31-9-17-4	2708	+1803		
C.W.N.G.L.H. & P. Co. 2	Lsd 3-1-10-18-4	2700	+1800		
C.W.N.G.L.H. & P. Co. 3	Lsd 14-6-10-17-4	2709	+1844		
C.W.N.G.L.H. & P Co. 6	Lsd 5-32-9-17-4	2723	+1798	+ 3	-597
Chin Prov. 1	Lsd 13-11-8-18-4	3010	+1840	+70	-500
Chin Prov. 2	Lsd 8-36-8-18-4	2975	+1815	+75	-509
Eureka #1	Lsd 9-19-8-13-4	2778	+1858	+178	-394

Name of Well	Location	Surface elevation	Top - Alberta formation	Top - lower Cretaceous	Top of Palaeozoic
Green Apex 1	Lsd 15-17-7-14-4	2704	+1994	+ 248	-258
Hi-Test 1	Lsd 7-24-9-17-4	2754	+1764	+ 44	-522
Hi-Test 2	Lsd 5-22-9-16-4	2708	+1768	+ 38	-498
Hi-Test 3	Lsd 7-18-9-16-4	2748	+1798	+ 88	-483
Purple Springs 1,	Lsd 15-11-10-15-4	2646	+1666	-64	-554
Conrad #1	Lsd 13-6-8-15-4	2938	+1938	+258	
Conrad #2	Lsd 3-7-8-15-4	2932	+1912	+ 332	-330
Imp. Clancey 1	Lsd 13-1-9-16-4	2702	+1772	+ 62	
Imp. Clancey 2	Lsd 14-10-9-16-4	2706	+1766	+ 76	
Imp. Clancey 3	Lsd 4-27-8-16-4	2884	+1854	+134	-401
Barnwell #1	Lsd 15-8-9-17-4	2795	+1745	- 5	-545?
Lethalta 1	Lsd 5-33-8-18-4	2868	+1818		
Taber 1	Lsd 12-9-9-17-4	2757	+1997	+ 327	-238
Major Taber 2	Lsd 4-9-9-17-4	2828	+1748	+ 38	-529
Major Taber 3	Lsd 14-9-9-17-4	2809	+1749	+ 39	
Midcontinent 1	Lsd 10-12-8-17-4	2961	+1881	+176	-354
Midcontinent 3	Lsd 13-1-8-17-4	2982	+1922	+232	-362
Midcontinent 4	Lsd 11-1-8-17-4	2995	+1905	+215	
Midcont. Univ.1	Lsd 12-17-9-17-4	2765	+1735	+ 85	-545
Noble #1	Lsd 14-33-8-17-4	2856	+1796	+ 86	

Name of Well	Location	Surface elevation	Top - Alberta formation	Top - Lower Cretaceous	Top of Palaeozoic
North Taber Royalties 1	Lsd 7-10-11-15-4	2508	+1813	- 82	-647
Plains Pet. #1	Lsd 14-25-9-17-4	2694	+1874	- 11	-586
Plains Pet. #2	Lsd 11-25-9-17-4	2705	+1865	-25	
Plains Pet. #3	Lsd 16-26-9-17-4	2706		- 34	-578
Taber 67-15-A	Lsd 14-15-9-17-4	2751	+1741	+ 1	
Taber 87-15-A	Lsd 13-15-9-17-4	2763	+1733	+ 33	-529
Taber C.P.R. 13-19-B	Lsd 8-19-9-16-4	2740	+1760	+ 50	-495
Taber 55-20-B	Lsd 11-20-9-16-4	2722	+1752	+ 52	-498
Taber 71-20-B	Lsd 4-20-9-16-4	2736	+1766	+ 56	
Taber 73-20-B	Lsd 5-20-9-16-4	2733	+1753	+ 83	
Taber C.P.R. 74-17-B	Lsd 5-17-9-16-4	2738	+1758	+18	-480
Taber C.P.R. 76-17-B	Lsd 12-17-9-16-4	2741	+1771	+ 61	-489
Taber Prov. 1	Lsd 9-18-9-16-4	2741	+1761	+56	-479
Taber 17-18-B	Lsd 16-18-9-16-4	2744	+1764	+44	
Taber 37-18-B	Lsd 15-18-9-16-4	2745	+1755	+55	
Taber 57-18-B	Lsd 14-18-9-16-4	2751	+1771	+ 61	
Taber C.P.R. 11-19-B	Lsd 1-19-9-16-4	2736	+1766	+66	

Name of Well	Location	Surface elevation	Top - Alberta formation	Top - Lower Cretaceous	Top of Palaeozoic
Taber 31-19-B	Lsd 2-19-9-16-4	2746	+1756	+32	
Universal Pet. of Alberta 1	Lsd 15-25-8-17-4	2835	+1825	+90	-698
Universal Pet. of Alberta 2	Lsd 3-24-8-17-4	2908	+1828	+108?	-426
Armelgra District					
Imp. Armelgra 2	Lsd 1-23-13-14-4	2555	+1455	-215	-793
Imp. Grantham 1	Lsd 1-29-13-15-4	2572	+1432	-208	-618
Imp. Scope 1	Lsd 13-21-12-14-4	2630	+1510	-120	-550
Imp. Scope 2	Lsd 13-24-12-15-4	2623	+1493	-177	-612

CHAPTER V

STRUCTURAL GEOLOGY

Southern Alberta may be divided into three main structural units, the Rocky Mountains, the foothills and plains. The westernmost of these is the region of the Rocky Mountains. The general structure here consists of a series of steep, west dipping fault blocks, repeating pre-Cambrian and Palaeogoic rocks. These fault blocks have been thrust along steep west dipping faults, and in the eastern part, pre-Cambrian rocks overlie Cretaceous strata.

Bordering the mountains to the east, is the narrow distmrbed belt of the foothills. The structure of the foothills is complicated, with the upper Cretaceous formation repeated by west dipping thrust faults. West of Lethbridge, the disturbed belt is about 8 - miles wide, but it increases in width to the northwest.

The foothills merge rather abruptly, with the monotonous flat or gently dipping strata of the plains. The dips are measured in feet to the mile, with faulting of rare occurrence. Slight undulations in the dips result in the development of local structures. The Lethbridge area is within the western limit of the plains province.

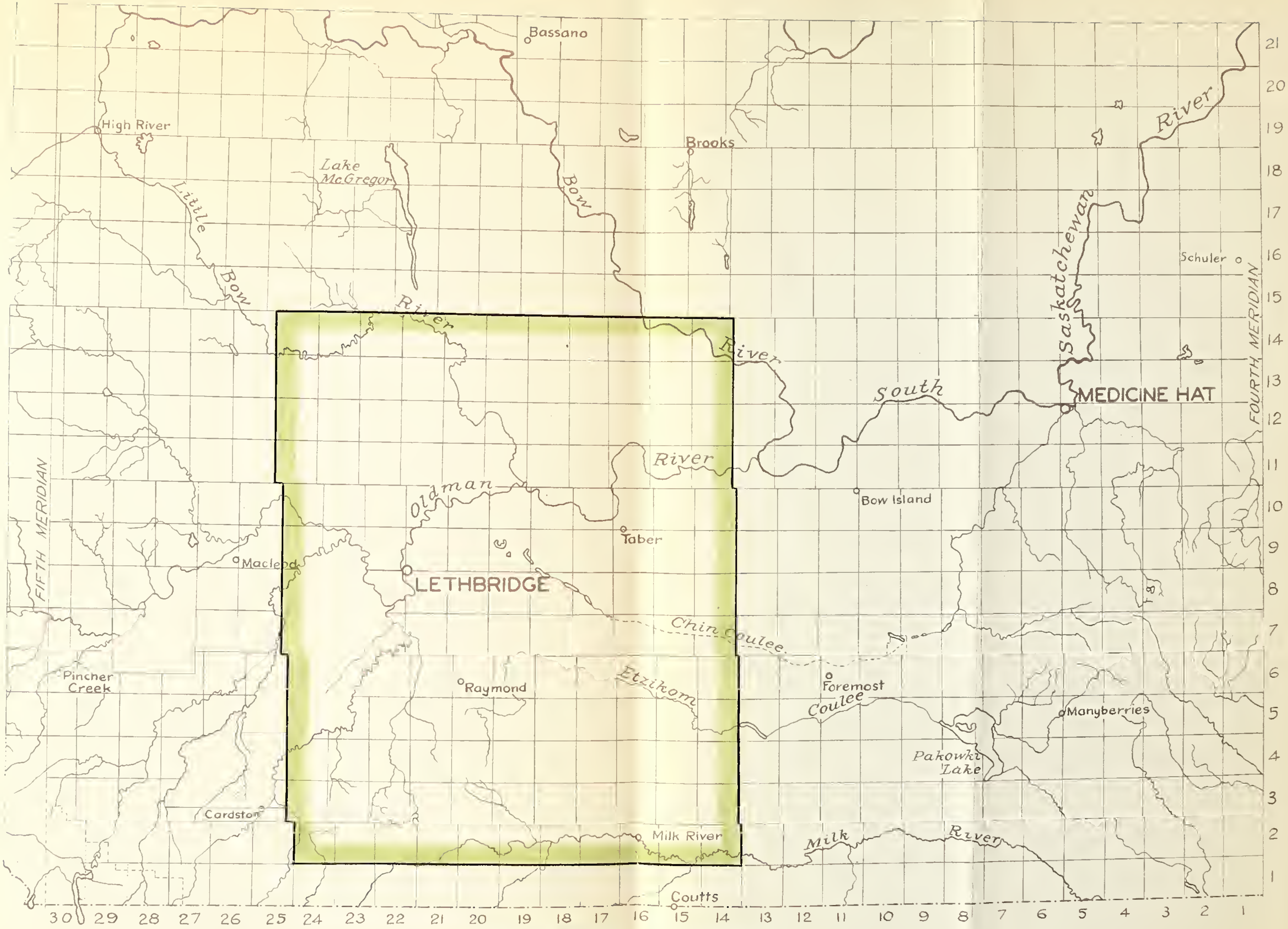
Regional Structure Maps

A series of three regional structure maps (Encl. 4,5,6) are included in this report. The area of the maps may be described as including townships 2 to 14, ranges 14 to 24, west of the 4th meridian. The area which these maps embrace is larger than, and includes the Lethbridge area proper. The maps are drawn on a horizontal scale of 1"-4 miles and the vertical structure contour interval is 100'. These maps are designed to show the relationship of the Lethbridge area to the regional structure of the southwestern plains.

The datum horizons on which the structure has been drawn are, the top of the Palaeozoic, top of the lower Cretaceous and top of the Alberta formation. The ideal condition in preparing structure maps is a datum which is a true plane. This condition is seldom encountered and the horizons which have been chosen here do not meet this condition. The top of the Palaeozoic is an erosion surface so that topographic as well as structural features are reflected in the contours. The top of the lower Cretaceous and the Alberta formation are both indefinite which may result in some discrepancy. In spite of these undesirable features, the writer believes these horizons serve the purpose of outlining the regional structure.

Regional Structure of Southern Alberta

The most prominent structural feature of the plains of Southern Alberta and Northern Montana is a north plunging anticline usually known as the Sweetgrass arch. It rises in the Little Belt Mountains of Montana and trends west of north into Alberta. The position of the axis is difficult to define, due to the flat nature of the crest. It is believed to cross the International Boundary in Township 1, Range 15 West of the 4th. Meridian. In Alberta it trends approximately due north for about 30 miles where it changes direction to the northeast. Local reversals in the plunge of the axis result in the formation of domes along the structure. One of the best known is the Kevin Sunburst dome in Montana, about 20 miles south of the Boundary line. From the Kevin-Sunburst dome, the direction of plunge is to the north, with the amount of plunge decreasing into Canada. The position of the northern edge of the Arch is not known exactly, due to the extremely gentle nature of the dip. Williams and Dyer (1930) report "On Red Deer river, the beds dip northward at a rate not exceeding 5' to the mile, but farther north in the Misty Hills and on Sounding Creek, they dip southward at an average rate of 6' to the mile. The evidence available, therefore suggests that the Arch terminates north of Red Deer river".



AREA OF REGIONAL STRUCTURE MAPS

1 inch = 18 miles

The Alberta Syncline flanks the Sweetgrass Arch to the west. The western side of the Alberta Syncline is involved in the disturbed strata of the foothills belt while its eastern limb is formed by the west dipping beds on the flank of the Sweetgrass Arch. The Lethbridge area is on the east limb of the Alberta syncline, which results in a general west dipping monoclinal structure for the area.

Structure on the Palaeozoic (Encl.4)

The top of the Palaeozoic is an erosian surface, often overlain by a detrital chert zone. It is possible that some of the contacts have been drawn at the top of the detrital zone rather than the true top of the Palaeozoic. The writer has used the contacts published by the Alberta Petroleum and Natural Gas Conservation Board (79).

The area of the map includes the western part of the Sweetgrass anticline. The north plunge on this structure is about 25' to 50' to the mile. Its western limb has a relatively steeper dip of 100' to the mile toward the axis of the Alberta syncline. The variation in dip is clearly shown by the difference in spacing of the contours.

Subsidiary folds have been developed on the Sweetgrass arch. Reflection of the north west plunging anticline at Del Bonita appears in the contours west of township 2-22-4 while part of the Twin River fold extends into township 2-20-4. The structure at Taber is developed on

a nose, plunging to the northwest. North of Taber, the structure is difficult to draw as few elevations of the limestone are known. An anticlinal fold plunging northwest has been outlined but this interpretation is questionable. The fold at Conrad plunges practically due north and is just west of the axis of the Sweetgrass arch.

The structure at Lethbridge may be described as monoclinal with no evidence of folding in the limestone. It is situated on the east limb of the Alberta Syncline which dips gently to the west at an average rate of 110' to the mile. The strike is north-south, with a slight swing to the north-east due to the reflection of the plunge of the Sweetgrass Arch, in the northern part of the district.

Structure on the Lower Cretaceous.

The top of the Lower Cretaceous is usually marked by a change from marine to continental facies. The contact is seldom sharp and differences in the point of contact may be expected. The writer has used the contacts published by the Alberta Petroleum and Natural Gas Conservation Board.

The main structural features are similar to those of the Palaeozoic. The north plunge of the Sweetgrass arch is about 30' to the mile with the dips on the west flank increasing from 40' to the mile near the crest to about 100' to the mile. The strike of the axis is about north-south.

The subsidiary folds of the Del Bonita and Twin River Areas are more pronounced and plunge to the northwest. It was necessary to draw a closed contour on the Twin River structure, indicating closure of at least 28'. The nose at Conrad is plunging to the northwest, showing a slight swing from the north-south direction on the limestone. A closed contour shows the closure on the fold to be at least 20'. The anticline is on strike with the structure at Taber but seems to plunge out to the south of it.

The structure at Taber is still a northwesterly plunging anticline which now consists of two anticlinal noses separated by a syncline, all plunging in a general northwesterly direction. The area to the north of Taber is practically flat with a regional dip to the northwest of about 16' to the mile.

The structure of the Lethbridge district differs somewhat from that on the Palaeozoic. The strike varies from N 20 E to north-south. This is due to a very gentle synclinal fold which modifies the general monoclinal structure of the region. The gentle nature of the fold makes the position of the axis difficult to describe but it crosses the Oldman River to the North of Lethbridge. A decided change in strike, to the northeast, occurs in township 14-21-4 as the formations start to close around the Sweetgrass Anticline.

Structure on the Alberta formation

The top of the Alberta formation is usually drawn at the first occurrence of a white speckled shale. However, these "white specks" are difficult to recognize to the west and have not been found in the foothills. Where they are not present, an arbitrary contact must be drawn as the change from the continental to marine facies is gradational. The writer has used the contacts published by the Alberta Petroleum and Natural Gas Conservation Board.(79)

The general features are not greatly different from those of the Lower Cretaceous and Palaeozoic. The Sweetgrass Arch plunges to the north at an average rate of 20' to the mile. The dip varies from 40' to the mile near the crest to 120' to the mile down the west flank. The axis trends about north-south.

The folds at Del Bonita and Twin River are pronounced, plunging gently to the northwest. The fold near Conrad is still quite definite, trending northwest but the folds which were noted in the vicinity of Taber on the Palaeozoic and Lower Cretaceous are now represented as closed anticlinal folds in townships 9 & 10-17-4. It is not possible to indicate detailed structure on maps of this scale, and other interpretations can easily be made. However, in order to present the general structure of the district, this interpretation presents the most reasonable

picture from the known data. Another unusual elevation occurs in township 11-15-4 which necessitates closing some of the contours to show a local high. Lack of information in the immediate vicinity makes the structure difficult to outline.

In the Lethbridge district, the syncline first noted on the Lower Cretaceous is better developed and quite definitely shown by the contours on top of the Alberta formation. It trends northwest from township 8-20-4 crossing the Oldman River north of the City of Lethbridge. It plunges out into the regional west dip in township 10-23-4. The strike of the axis is about N65°W.

The larger faults which outcrop on the Oldman River in township 9-21-4 and township 8-22-4 have been indicated on the map. The fault at Diamond City is not considered to carry to depth (Encl.3, Section A-B) and the contours are not affected by it here. The fault in township 8-22-4 involves Bearpaw and Oldman beds at the surface, with a displacement of 100' on the outcrop. Russell and Landes (54, 1940) believe this fault carries to sufficient depth to involve the Alberta shale (Taber Sheet #565-A) and their interpretation is followed here. The contours would present a similar structural picture if the fault was disregarded.

The fault zone at Monarch in townships 9 and 10-23-4 has also been indicated. Lack of information makes

the detailed structure impossible to interpret, but the regional structure is fundamentally monoclinal, with a gentle dip to the west. The depth to which the faulting carries is not known, but it is probable that the Alberta formation is not affected.

Structure Map of Lethbridge Coal Field.

A structural map of the Lethbridge coal field is included in this report (Encl. #2) It includes townships 8 to 11, ranges 21 to 23 west of the 4th. Meridian. The horizontal scale of the map is 1"=1 mile, and the vertical structure contour interval is 50'. The map is designed to outline the attitude of the Lethbridge coal seam throughout the district, and in its preparation, full use has been made of all available elevations on the coal. The larger faults, with a displacement of sufficient magnitude to effect the contours, have been included on the map.

Structure of Lethbridge Coal Field

In the Lethbridge district, the structure is very gentle, consisting of a series of interfingering anticlines and synclines. Their axes trend northwest-southeast, and the folds plunge gently to the northwest.

The syncline, which was first noted in the structure of the Lower Cretaceous and Alberta formations, is the prominent structural feature of the coal field. Its axis crosses the Oldman River in the N.E.¼ of section 24-9-22-4 in a direction about N45°W. The average rate of

plunge is 80' to the mile in a northwesterly direction.

The syncline is cut by a normal fault trending obliquely to its axis in a direction N75°E. The fault does not outcrop, but was encountered during mining operations. Where it occurs in the mine shaft in the N.W.¼ of Section 6-9-21-4, the throw is about 30'. The mine plans show that the fault crosses the Oldman River in Section 1-9-22-4. The downthrow strata are on the northeast side of the fault.

To the south, the syncline is flanked by a low anticlinal fold. The axis of this structure passes through the centre of section 32-8-22-4, trending in a direction N55°W. The plunge averages less than 100' to the mile, but varies from 50' to 150' to the mile, increasing to the northwest. The dips on the southwest flank appear to be greater than those of the northeast limb, but the available information is not sufficient to warrant a positive statement.

The southwest flank of this anticline is cut by a normal fault, which crosses the Oldman River in Section 11-8-22-4. The strike of the fault is about N30°W. The fault is exposed on the Oldman River and involves the Bearpaw and Oldman formations at the surface. Sproule (1940) estimates a displacement of 100' at the river. The downthrown side is to the southwest, where the coal is present. The coal has been removed by

erosion on the north side of the fault. The fault is projected to the north on the basis of the coal. No coal was encountered in the Texas-Imperial well in Sec. 22-8-22-4 while a test hole in the S.W.¼ of 28-8-22-4 found the coal to be present. It would seem that the fault lies between these two drill holes. The projected fault cuts across the crest of the anticline in Sec. 22-9-22-4, passing over to the north flank. South of the river, the fault was encountered in the G. Rollingson mine lsd 2-11-8-22-4. Beyond the mine, the extent of the fault is not known.

To the north of the Lethbridge syncline is a very flat anticline (Encl. #-Sect.A-B and C-D) with a slight reversal on the north side. The axis is difficult to define, but is believed to strike about N35°W, and passes through the S.W.¼ of Sec. 36-10-22-4. This fold plunges to the northwest at an average rate of 55' to the mile. There is some variation in the plunge, from 30' to the mile increasing to 100' to the mile to the northwest.

A normal fault is exposed in the Oldman River Valley near Diamond City in the N.W.¼ of Section 31-9-21-4. The fault cuts the southwest flank of this structure. On the outcrop, the Lethbridge coal seam is in fault contact with Bearpaw shales. The dip of the fault plane is 70°-80° to the southwest, and the strike is about N30°W. It is not possible to state the

amount of displacement, as the coal seam, which is the marker bed, is downfaulted below river level. From stratigraphic evidence, it is estimated to be about 60', as the transition beds above the coal, are also below river level. Considerable downward drag was observed on the upthrown side of the fault.

The fault was encountered in the Chinook mine in lsd 7-12-10-22-4, and resulted in the loss of the coal seam. A series of bore holes were drilled in an effort to relocate the seam across the fault. One was drilled 52' vertically upwards, another horizontally for 40', a third downward for 22' and a fourth at an angle of 45° for 45'. None of these borings were successful in relocating the coal. No estimate of the displacement on this fault can be made, since the mine is now abandoned and first-hand information cannot be obtained. It is the writer's opinion that the mine was on the downthrown side of the fault.

This fault is considered to continue south of the Oldman River at least to lsd 12-29-9-21-4 where it was encountered in the Royal Lethbridge Collieries Mine. Here the displacement varies from 15' to 40' with the downthrown side still on the southwest. The strike of the fault is, here, about N45°W, although it has a sinuous trend as mapped on the mine plan.

The folds of the Lethbridge district are exceedingly gentle, trending in a general northwesterly direction. These folds are believed to plunge out into the regional west dip of the east flank of the Alberta Syncline.

Minor Faults

There are numerous faults of small displacement which cause minor breaks in the main coal seam and the contiguous formations in the Lethbridge coal field. They are common throughout the district and present a constant source of annoyance and expense to the mining companies. In addition, three normal faults of larger displacement are known and have been described in this thesis with the structure of the district. They will not be included here.

Normal, reverse and pivot faults have been mapped with the normal faults most common. The amount of displacement of the strata, due to the faulting, varies from a few inches to as much as 20', with 4' to 6' as the average. The fault planes usually dip at steep angles, with the majority between 35°-40°. Readings as low as 20° were recorded.

Slickensiding is not uncommon and is generally accompanied by some crushing of the coal along the fault plane. Wherever evidence of grooving was observed, the striations were coincident with the dip of the fault

plane and no evidence of a horizontal component noted. This evidence indicates that the faults may be classified as dip slip faults, with no strike slip component.

The drag on the upthrown side of the fault at Diamond City has been mentioned (page 107). Evidence of drag was also observed along the fault plane in some of the smaller faults. Some of the faults have a cavity developed between the walls. Water seeping down the fault plane from the surface is trapped, which causes a flow of water into the workings when an outlet is provided by mining operations. These cavities usually drain in a short time. This condition was described by several mining officials but was not observed by the writer. It seems probable that these cavities are associated with normal faults, the separation of the two walls resulting from tension.

Monarch Fault Zone

The Monarch Fault zone consists of a series of west dipping fault blocks separated by thrust faults. The fault zone is exposed on the Oldman River in Section 31 and 32, township 9 and Section 6, township 10 - range 23-4. The fault blocks repeat the basal St. Mary river, Blood Reserve and upper Bearpaw beds. The dip of the fault planes is variable, ranging from 20° to vertical. The strike of the faults range from N25°E to N20°W.(76)

Russell (51, 1931) made a detailed study of the eastern part of the Blood Indian Reserve and found that

There was no continuity of the disturbance along the strike. Rather, the disturbance is of local extent insofar as known at present. He found the stratigraphic displacement was usually less than 100' in spite of the apparent intensity of the faulting.

The writer does not believe these faults carry to depth. The structure on the Alberta formation (Encl.6) does not reflect the surface disturbance at depth. It seems probable that the faults die out rapidly, possibly with the formation of minor undulations in the strata to the west.

Fault Trends

Mine plans of the district create the impression that the faults have no general trend. Individual faults as mapped on the mine plans, cut the coal seams in any direction, in many cases, follow a very sinuous course with a wide variation in the strike. This condition may be exemplified by the following 4 examples. The strike of the fault plane has been measured at different points along the trace of the fault in each case.

Fault # 1	Fault # 2	Fault # 3	Fault # 4
N20°E	N70°W	N - S	N20°E
N10°E	N84°E	N25°E	N50°E
N10°W	N65°W	N85°E	N10°E
N15°W	N30°W	N55°E	N15°E
N45°W			N50°E
N - S			N 5°E

It would be impossible to plot the faults of the

TABLE # 2

Mine Number	Name	Location	Number of Faults Measured	Trend	Basis
54	Federal Coals Ltd.	lsd 5-36-8-22-4	12	N15°W	7 faults
174	North American Collieries Limited	lsd 2-21-9-22-4	117	N15°W to N15°E	68 faults
247	Chinook Coal Co.	lsd 7-12-10-22-4	67	N15°W	31 faults
1095	J. C. Chester	lsd 9-20-9-21-4	46	N45°E to N45°W	9 faults 7 faults
1263	Lethbridge Collieries Ltd.	lsd 11-30-10-21-4	49	N45°W	20 faults
1464	Lethbridge Collieries Ltd.	lsd 3-2-9-22-4	78	N15°E	31 faults

Lethbridge district on a map of reasonable scale. In order to establish the relation of the faults to the structure, the following method was adopted. The strike directions of the faults were measured as mapped on the mine plans of several of the larger mines. The strike directions for each mine were plotted on separate circles divided into 15° segments. The predominant direction of fault trend for each of the mines was determined from these circles and plotted on the structure map of the district (Encl.6A). The data which was used in this compilation is outlined in Table # 2.

The minor faults of the J. C. Chester Mine cut the coal in two main directions, N45°W corresponding to the strike of the local structure and N45°E, normal to it. In Lethbridge Collieries Mine #1263, the trend is N45°W, with no normal component. The larger faults in Section 11-8-22-4 and Section 31-9-21-4 are also approximately parallel to the local folds.

In the other mines, the minor faults trend obliquely, in relation to the strike of the local folding. They occur in a zone between N15°W and N15°E. and no normal component has been developed. The large fault in Section 6-9-21-4 trends in a direction N75°E which is roughly normal to the main zone.

The writer believes there are two main sets of fault trends, one coinciding with the strike of the

structure and normal to it and the other, distinctly oblique to the axes of the folds, with no well developed normal component.

Cleavage

There are two cleavages or cleats in the coal. The main cleavage trends N50°E and the secondary cleavage is developed normal to it in a direction N40°W. The prominent cleavage is readily observed on the mine plans, as all the mining is "on the cleavage". A clean break, resulting in a smooth surface on the coal along the major cleavage is typical. These cleats occur less than a foot apart and often only inches separate them. The secondary cleavage is not so well developed, and the coal breaks with a pronounced conchoidal fracture.

Rolls

"Rolls" are of common occurrence in the Lethbridge field. These involve a local increase in dip to as much as 10°. The beds rise to a maximum elevation from which they slope away until the normal level is regained. No break in the strata result from these rolls.

Profile Sections

Three profile sections (Encl.#3) are included in this report. Sections A-B and C-D have been drawn normal to the axis of the syncline, and section E-F is parallel to it. The horizontal scale is 1"= 1 mile and

and an exaggerated vertical scale of 1"=1000' has been used due to the gentle nature of the folding. Surface points of reference have been indicated as well as common points of intersection. The location of these sections are included on the Geological Map (Encl. #1). The estimated elevation of the base of the glacial cover is based on surface observations and subsurface data.

Section A-B illustrates the slight asymmetry of the Lethbridge syncline, with a somewhat steeper dip on the north limb. The syncline is the prominent fold while the anticlines flanking it show only a slight reversal in dip. The fault at Diamond City is not considered to extend to any depth, and dies out with a gentle increase in dip in the underlying formations. The location of the coal beneath river level is on the downthrown side of the fault.

Section C-D has been drawn farther down the plunge of the syncline. Here the syncline is broader with more gently dipping limbs. The anticlines are very flat, with gentle reversals in dip still evident. No faults of sufficient magnitude to effect the strata are known to occur along the line of section.

Section E-F is coincident with the axis of the syncline and illustrates the plunge of this fold. The dip is to the northwest, with only slight variations in

the pitch. No faults worthy of consideration occur along the line of section.

For the vertical scale of the sections, the Lethbridge coal seam may be considered as coincident with the Bearpaw-Oldman contact. An examination of the sections shows the greatest depth of overburden above the coal to occur along the axis of the syncline, and is least above the anticlines flanking it. These depths increase to the northwest, as the plunge of the structures carries the coal to lower elevations.

Structural History

The earliest known folding on the southern plains occurred between Madison and Ellis time. Romine (59-1929) noted considerable thinning in the "Kootenai" and Ellis formations over the crest of the Sweetgrass Arch in Montana. Michener (42-1934) reported a similar thinning in the interval between the base of the Ellis and top of the Virgelle sandstone. He found the thinnest part to correspond closely to the axis of the anticline. This evidence indicates that the Sweetgrass anticline was first uplifted about the end of the Palaeozoic and is possibly a reflection of the Appalachian disturbance which occurred at the end of the Pennsylvanian.

No further disturbance occurred until the main uplift of the Rocky Mountain Revolution. Warren (1939) considers the culmination of the uplift was in late

Eocene. He also suggests a general uplift about the beginning of Pliocene time after the Cypress plain had been eroded to base level.

The effects of the mountain building extended to the east, resulting in the disturbed belt in front of the mountains and the gentle folds of the western edge of the plains. The Sweetgrass Arch was further accentuated during this period.

A. C. Lawson (36-1925) suggests post Oligocene uplift in the plains and mountains, due to isostatic adjustment, resulting from the removal of a thick prism of sediments by erosion. Lawson, using assumed values for the specific gravities of the surface and deep rocks, suggests an uplift of 1680' in the vicinity of the Cypress Hills. He believes the amount of uplift increases to the west, since a greater thickness of material has been removed.

Rutherford (56-1941) suggests that differential uplift occurred during the glacial or post glacial period, to explain the presence of Keewatin glacial material at high altitudes in southwestern Alberta. He believes the amount of uplift increases from north to south, to about 2000' in the southwest. This figure is based on present elevations of patches of till along the western boundary of the Keewatin drift.

Character of Deformation

During the period of mountain building, strong

easterly directed forces prevailed. This is indicated by the disturbed belt and Lewis thrust of southwestern Alberta. Here the structure is marked by major west dipping faults along which the strata have been thrust to the east. The major part of this stress was dissipated in the folding of the foothills region with the remainder relieved in the final uplift of the Sweetgrass Arch.

The forces of deformation were undoubtedly very complex, resulting in a structural alignment which could not have resulted from simple compression. Changes in the strike along the mountains and foothills indicate that the stresses were not uniform. The strike in front of the Lewis thrust is N30°W at the International Boundary swinging to N60°W and finally north-south in township 7, range 1, W.5th. meridian farther to the north. The variation in the intensity of the stress would tend to result in the development of an unbalanced or torsional stress acting as a couple.

The main stresses were transmitted by the more competent Palaeozoic rocks at depth. These stresses were relieved in part by folding with the formation of the local northwesterly plunging folds in the limestone which are developed on the Sweetgrass Arch. In addition to these deep seated forces, some of the stress was probably transmitted by the more competent members of the

younger formation. The thrust faulting at Monarch and the folding at Lethbridge is probably the result of forces which were transmitted by the relatively more competent St. Mary River, Oldman and Foremost formations. The depth of the faulting at Monarch is not known, but the folds at Lethbridge do not extend to the limestone.

Relation of the Faults to other Structures

The axes of the folds at Lethbridge strike approximately N.45°W. The minor faults are believed to follow two main sets of trends, one of which coincides with the folding and the other in a zone N.15°E. to N.15°W. oblique to the axes of these structures. The cleavage directions in the coal are parallel to the folding and normal to it.

This variation in the directions of faulting in relation to the folding lends support to the suggestion that the stresses acted as a couple. A purely compressive force would result in the development of faulting parallel to the trend of the folds and normal to it. Faults trending obliquely to the axes would be less likely to develop.

A couple causes deformation by three different stresses, namely, compressive stresses, tensional stresses and shearing stresses. The folding, and associated faults parallel to the strike of the folds (N.45°W.) are the result of compression. The faults trending N.45°E. are

due to tension, which develops in a direction normal to the compressive stresses. The shearing stresses develop in directions oblique to the compressive and tensional stresses and here occur in a zone between N.15°W. and N.15°E. The faults at Monarch are believed to be due to these shearing stresses since they strike between N.25°W. and N.20°E.

Age of Faulting

The relation of the faults to the structure suggests that they were, in large part, formed during the folding or possibly following the release of pressure due to the folding. This folding resulted from the mountain building which occurred in late Eocene. It is possible that some of the faulting occurred after Eocene time, due to uplift following the removal of great thicknesses of material by erosion.(36,1925) Rutherford (56,1941) has suggested post-glacial uplift but none of the faults in the Lethbridge district are known to involve the overlying glacial deposits The writer believes that any faulting which may have occurred due to uplift, after Eocene time, would be along planes of weakness developed during the period of mountain building.

APPENDIX

EARLY HISTORY OF MINING AT LETHBRIDGE

The early history of mining in the Lethbridge area is mainly the story of the Galt family (59). Dawson (18,1884) mentioned that the coal was being extracted at Sheran's mine at "Coal Banks" in 1882. It was mined from the outcrop and transported by teams to the Mounted Police barracks which were established at Macleod in 1874. Magrath (39, 1935) in a review of the early history, states "I believe we found but one squatter on land in the 600 miles between Fort Ellice on the Assiniboine River and Fort Macleod - and that one was Nicholas Sheran on the west side of the Belly River (Oldman) at the "Coal Banks". Magrath was speaking of a journey which he made as surveyor in 1881.

Elliott Galt, while inspecting Indian Agencies in the west in 1879 saw the coal exposed on Oldman River at Coal Banks. He interested his father, Sir Alexander Galt, Canadian High Commissioner in London. He and some of his English associates , including Sir William Lethbridge, formed the Northwestern Coal and Navigation Co. in 1882. At this time, the only means of communication with the outside world was by bull train and prairie schooner to Fort Benton, Montana.

Mining operations commenced in 1883. Boats and barges were constructed at Lethbridge to transport the

coal to Medicine Hat by river. In 1884, the first coal was shipped by this method but it was found to be infeasible. It was decided to build a railway to Dunmore and this project was started in 1885 and completed in September of the same year. Lethbridge was named in 1885, after Sir William Lethbridge.

In 1886 the Canadian Pacific Railway was completed from coast to coast and passed through Dunmore. In 1889, the Alberta Railway and Coal Company was formed and absorbed the Northwestern Coal and Navigation Company. A line to Coutts was constructed giving an outlet to the market in Montana.

During the intervening years to 1900, development of the irrigation system progressed, with the Galts among the foremost leaders. The Alberta Irrigation Company was formed by a charter obtained by Sir Alexander Galt in 1893. The company was reorganized in 1899 as the Canadian Northwest Irrigation Company. A narrow guage railway to Cardston from Sterling was completed in 1902. It was known as the St. Mary River Railway Company and was organized by Elliott Galt.

In 1904, the three companies - the Alberta Railway and Coal Company, Canadian Northwest Irrigation Company and St. Mary River Railway Company were amalgamated into the Alberta Railway and Irrigation Company. By 1908, the

Canadian Pacific Railway was in control and acquired the entire holdings of these companies in 1911.

Mining operations have been continued by the Canadian Pacific Railway since 1911 and at present, the two largest mines in the district belong to this company. Numerous other companies have been formed and aided in the development of the coal resources of the district. This industry, combined with a rich agricultural community has resulted in the establishment of the city of Lethbridge as one of the foremost centres in the province.

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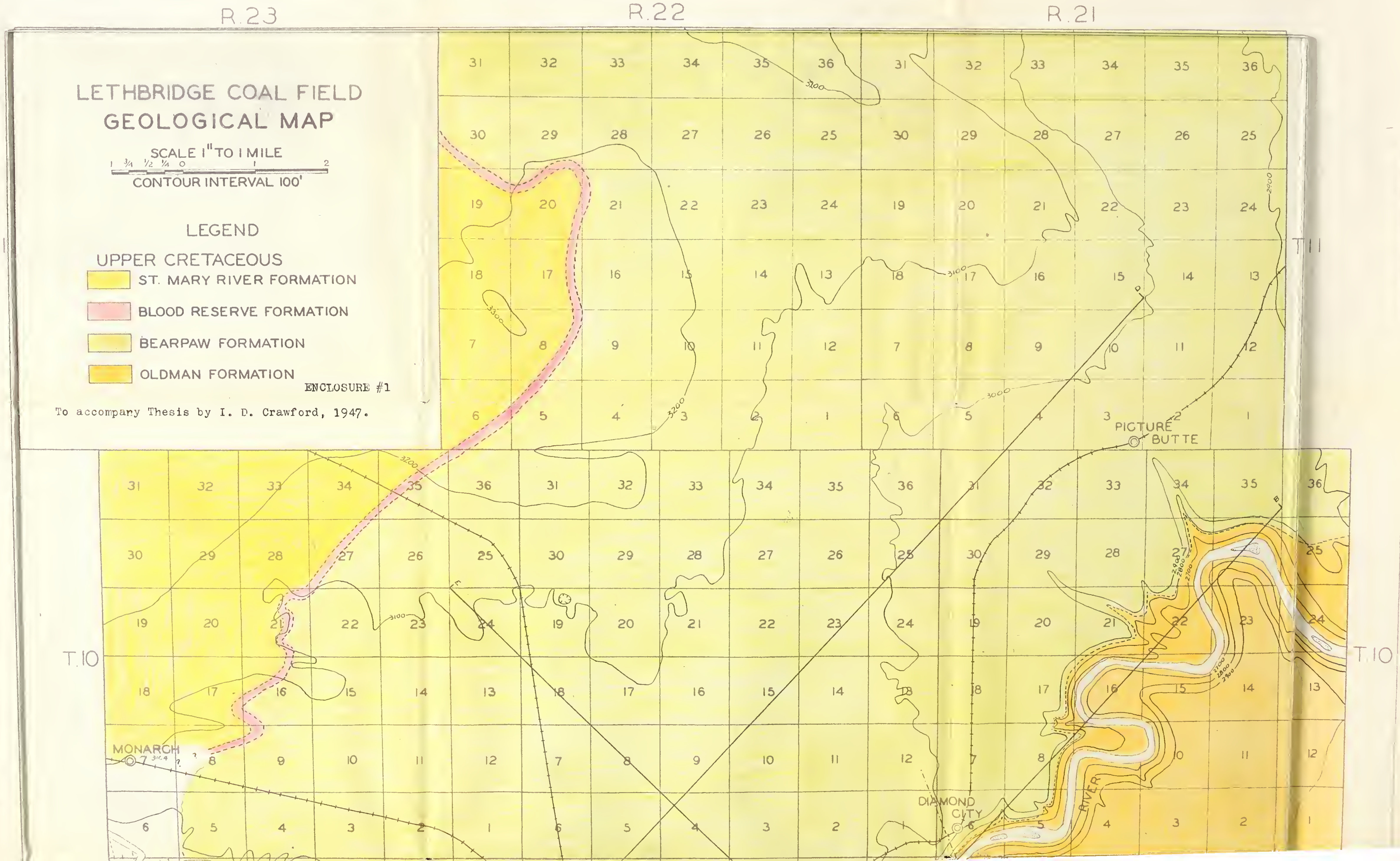


LETHBRIDGE COAL FIELD GEOLOGICAL MAP

SCALE 1" TO 1 MILE

CONTOUR INTERVAL 100'

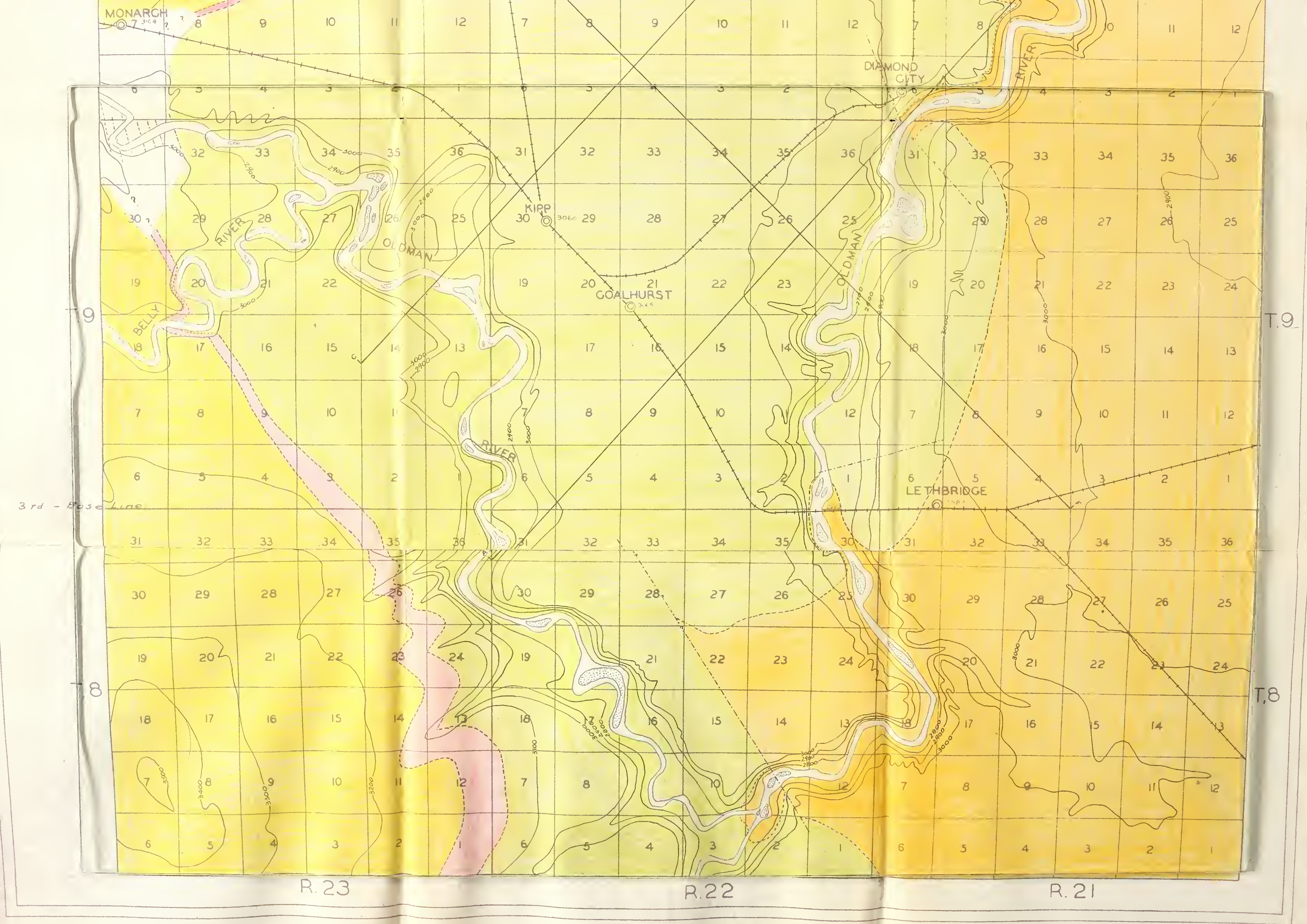
LEGEND

UPPER CRETACEOUS

- ST. MARY RIVER FORMATION
- BLOOD RESERVE FORMATION
- BEARPAW FORMATION
- OLDMAN FORMATION

ENCLOSURE #1

To accompany Thesis by I. D. Crawford, 1947.


MONARCH
DIAMOND CITY
KIPP
COALHURST
LETHBRIDGE
OLDMAN RIVER
OLDMAN RIVER
OLDMAN
RIVER
BELLY
RIVER
3rd - Base Line
T.9
T.9
T.8
T.8
R.23
R.22
R.21
3000
2900
2800
3100
3200
3400
3500

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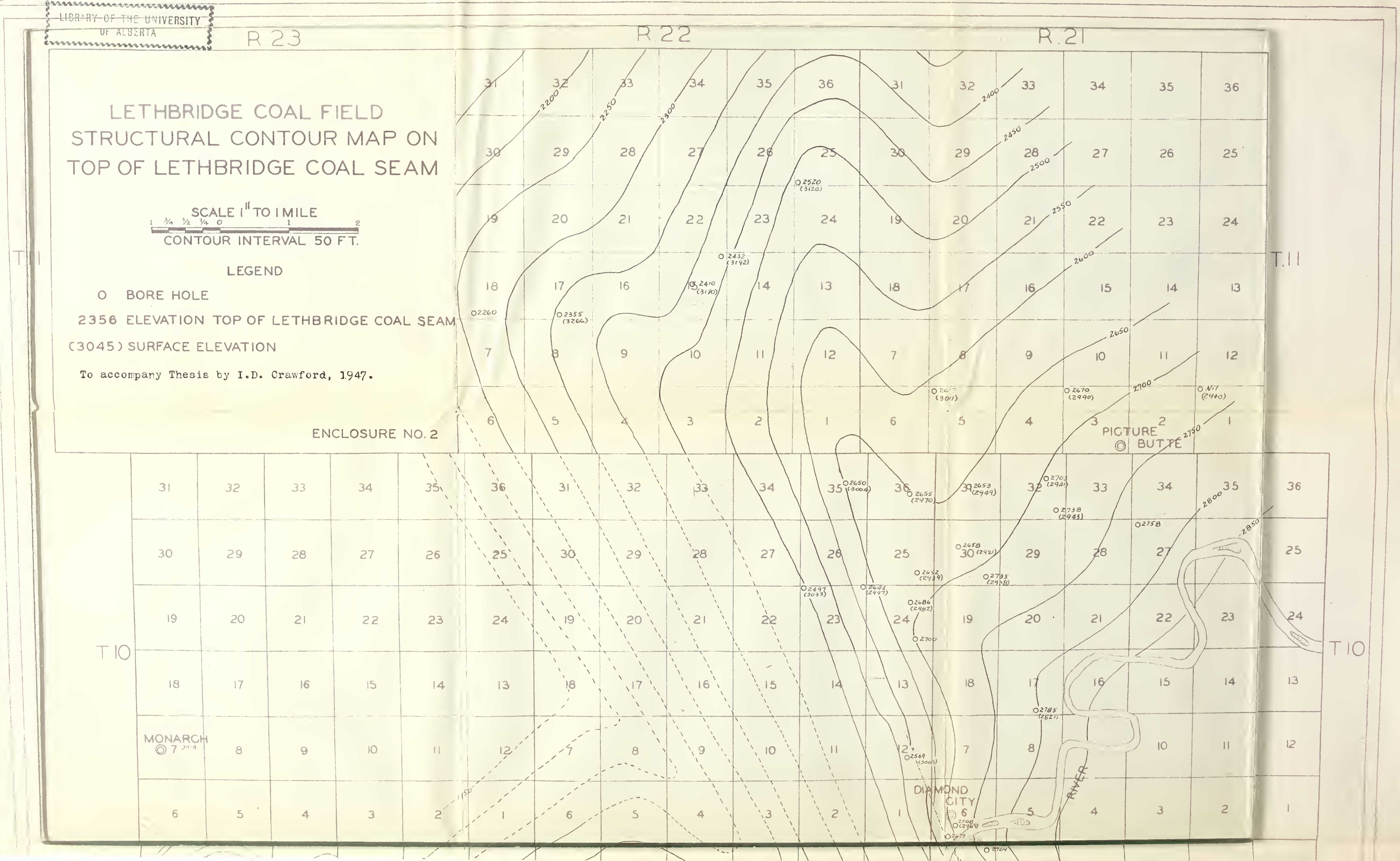


LETHBRIDGE COAL FIELD STRUCTURAL CONTOUR MAP ON TOP OF LETHBRIDGE COAL SEAM

SCALE 1" TO 1 MILE

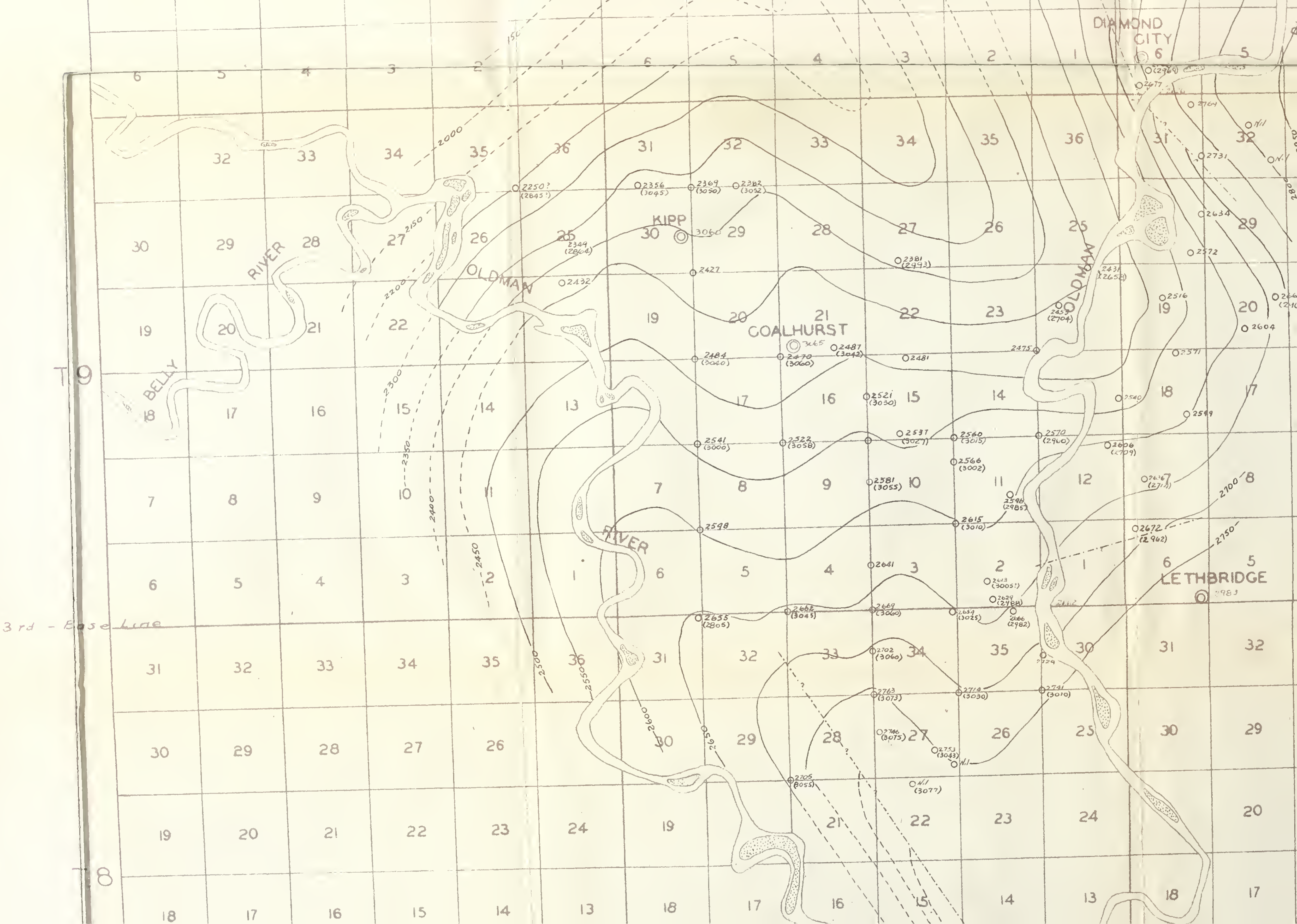
CONTOUR INTERVAL 50 FT.

LEGEND

O	BORE HOLE
2356	ELEVATION TOP OF LETHBRIDGE COAL SEAM
(3045)	SURFACE ELEVATION

To accompany Thesis by I.D. Crawford, 1947.

ENCLOSURE NO. 2



DIAMOND CITY
KIPP
COALHURST
LETHBRIDGE
OLDMAN
RIVER
OLDMAN RIVER
BELLY RIVER
OLDMAN
T 9
T 8
3rd - Base Line
2000
2150
2200
2300
2350
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2500
2550
2600
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2700
2750
2800
2250? (2845?)
2356 (3045)
2369 (3050)
2382 (3052)
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2344 (2864)
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2381 (2993)
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2453 (2704)
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2655 (2805)
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2702 (3060)
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2714 (3030)
2791 (3010)
2763 (3073)
2746 (3075)
2753 (3043)
Nil
2705 (3055)
Nil (3077)
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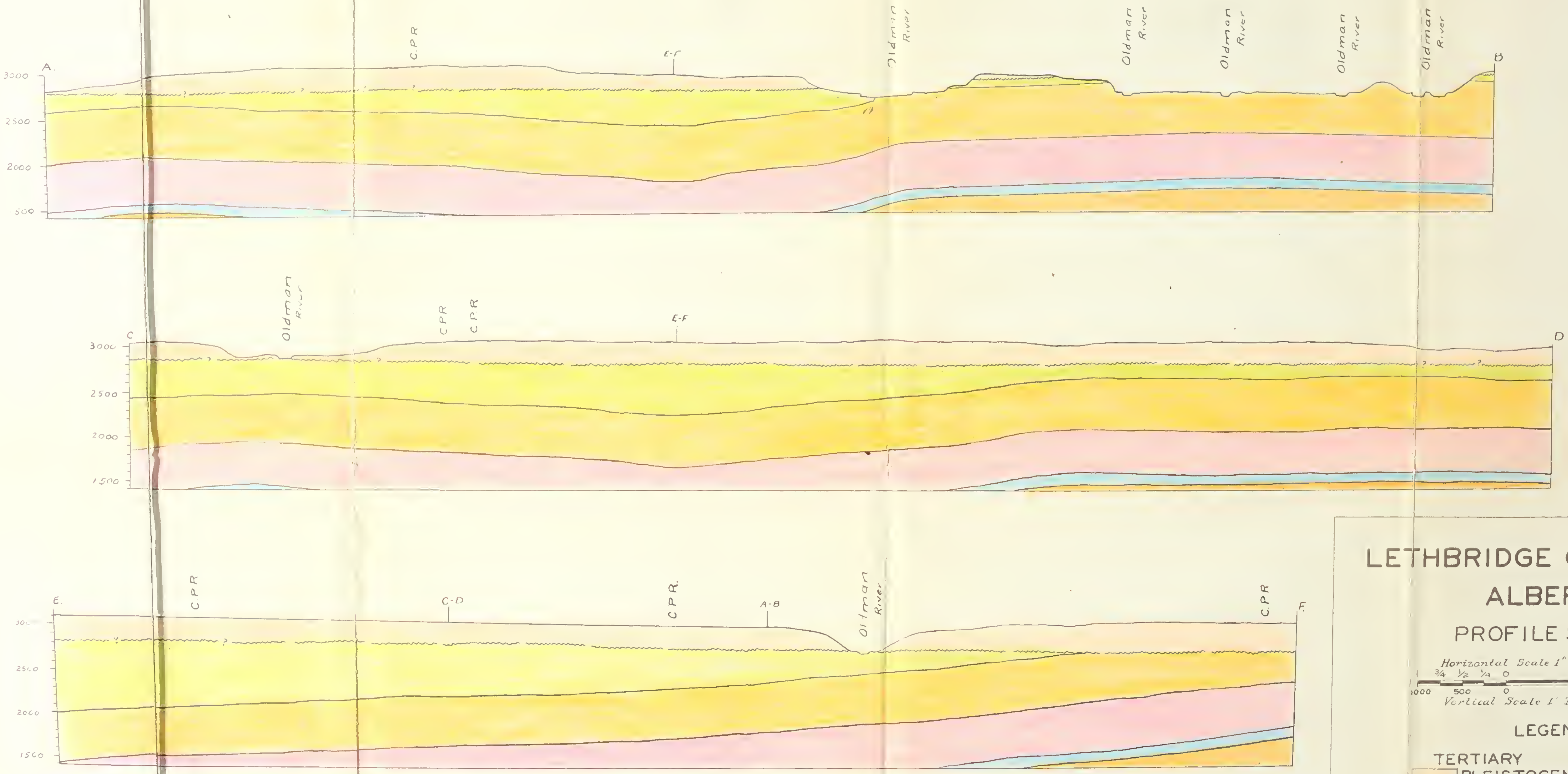
2549
?



LETHBRIDGE COAL FIELD
ALBERTA

PROFILE SECTION

Horizontal Scale 1" To 1 Mile

3/4 1/2 1/4 0 1 2 MI

1000 500 0 1000 2000 FT.

Vertical Scale 1' To 1000 Feet

LEGEND

TERTIARY
▨ PLEISTOCENE

UPPER CRETACEOUS
▨ BEARPAW FORMATION
▨ OLDMAN FORMATION
▨ FOREMOST FORMATION
▨ PAKOWKI FORMATION
▨ MILK RIVER FORMATION

ENCLOSURE NO.3

To accompany Thesis by I.D. Crawford, 1947.

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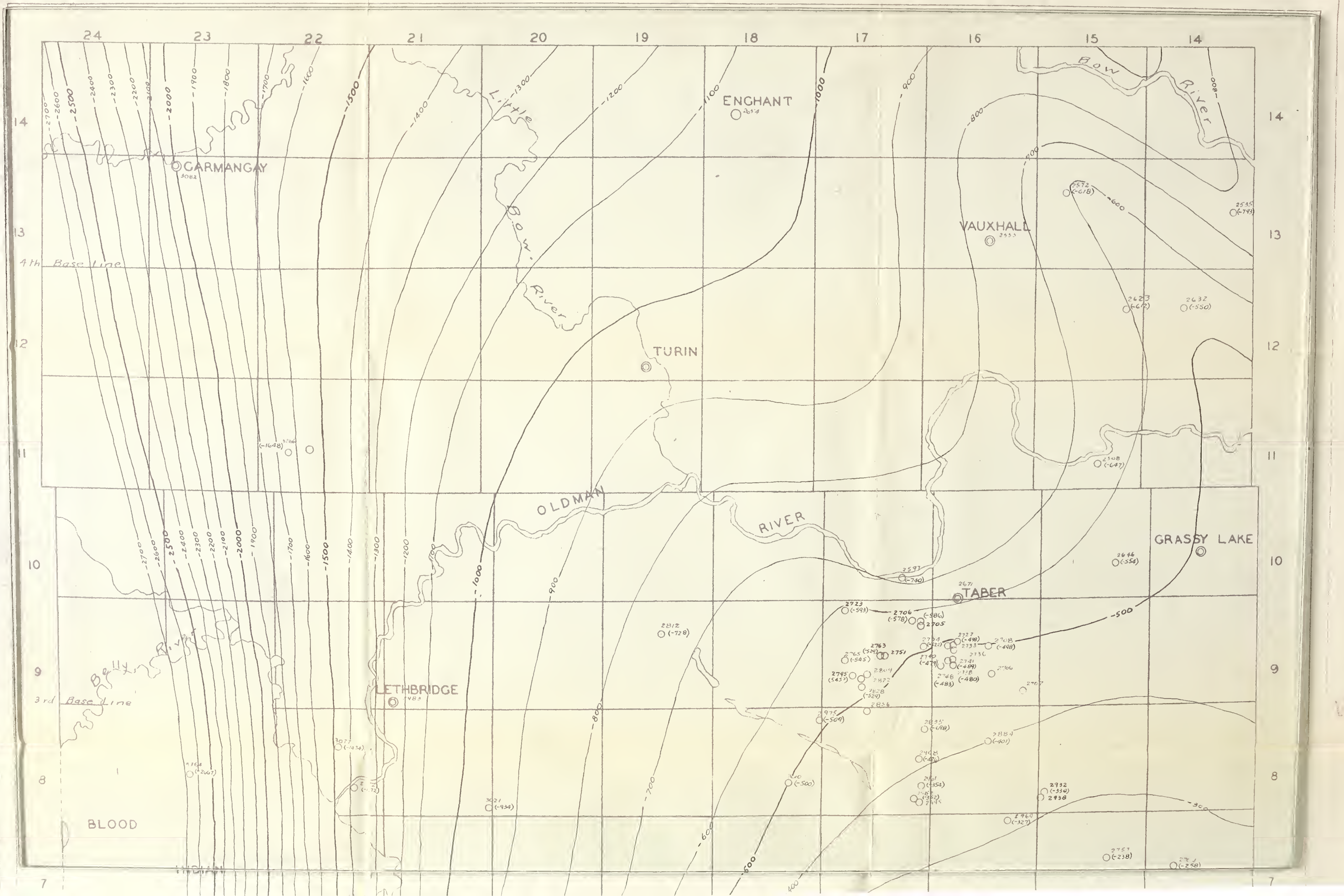
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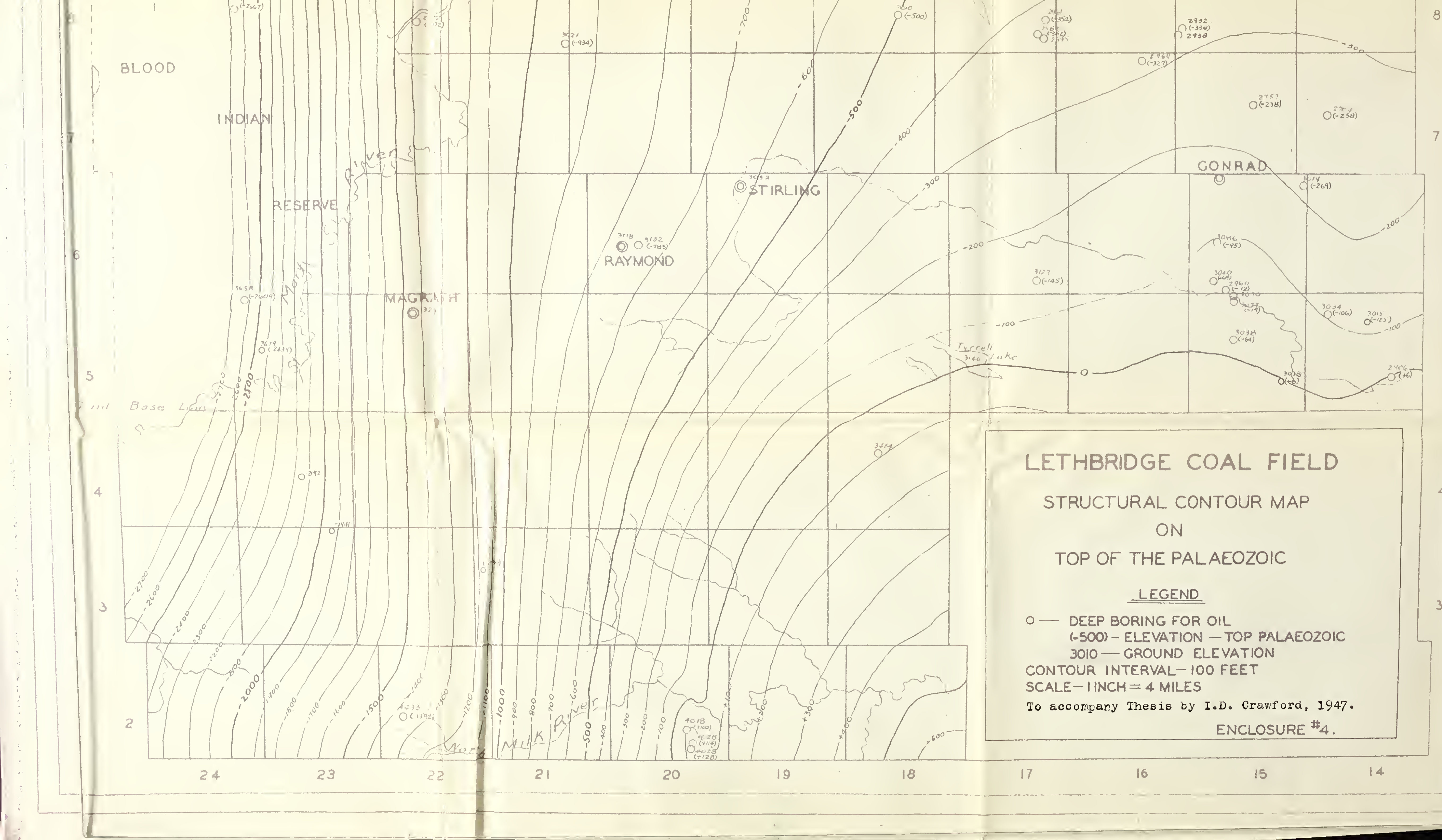
7
4th Base Line
3rd Base Line
CARMANGAY
3082
ENCHANT
VAUXHALL
TURIN
GRASSY LAKE
TABER
2671
LETHBRIDGE
BLOOD
INDIAN
Little Bow River
Bow River
OLDMAN RIVER
Belly River
-2700
-2600
-2500
-2400
-2300
-2200
-2100
-2000
-1900
-1800
-1700
-1600
-1500
-1400
-1300
-1200
-1100
-1000
-900
-800
-700
-600
-500
-400
-300
2572 (-618)
2595 (-743)
2623 (-612)
2632 (-550)
2508 (-647)
2646 (-554)
2597 (-740)
2723 (-593)
2706 (-578)
(-586)
2705
2812 (-728)
(-1648)
2727 (-498)
2708 (-498)
2763 (-524)
2751
2765 (-545)
2795 (-545)
2975 (-509)
2835 (-498)
2884 (-401)
3077 (-1434)
3021 (-934)
2932 (-339)
2938
2960 (-327)
2757 (-238)
(-258)



LETHBRIDGE COAL FIELD

STRUCTURAL CONTOUR MAP
ON
TOP OF THE PALAEOZOIC

LEGEND

○ — DEEP BORING FOR OIL
(-500) – ELEVATION — TOP PALAEOZOIC
3010 — GROUND ELEVATION
CONTOUR INTERVAL – 100 FEET
SCALE – 1 INCH = 4 MILES

To accompany Thesis by I.D. Crawford, 1947.

ENCLOSURE #4.

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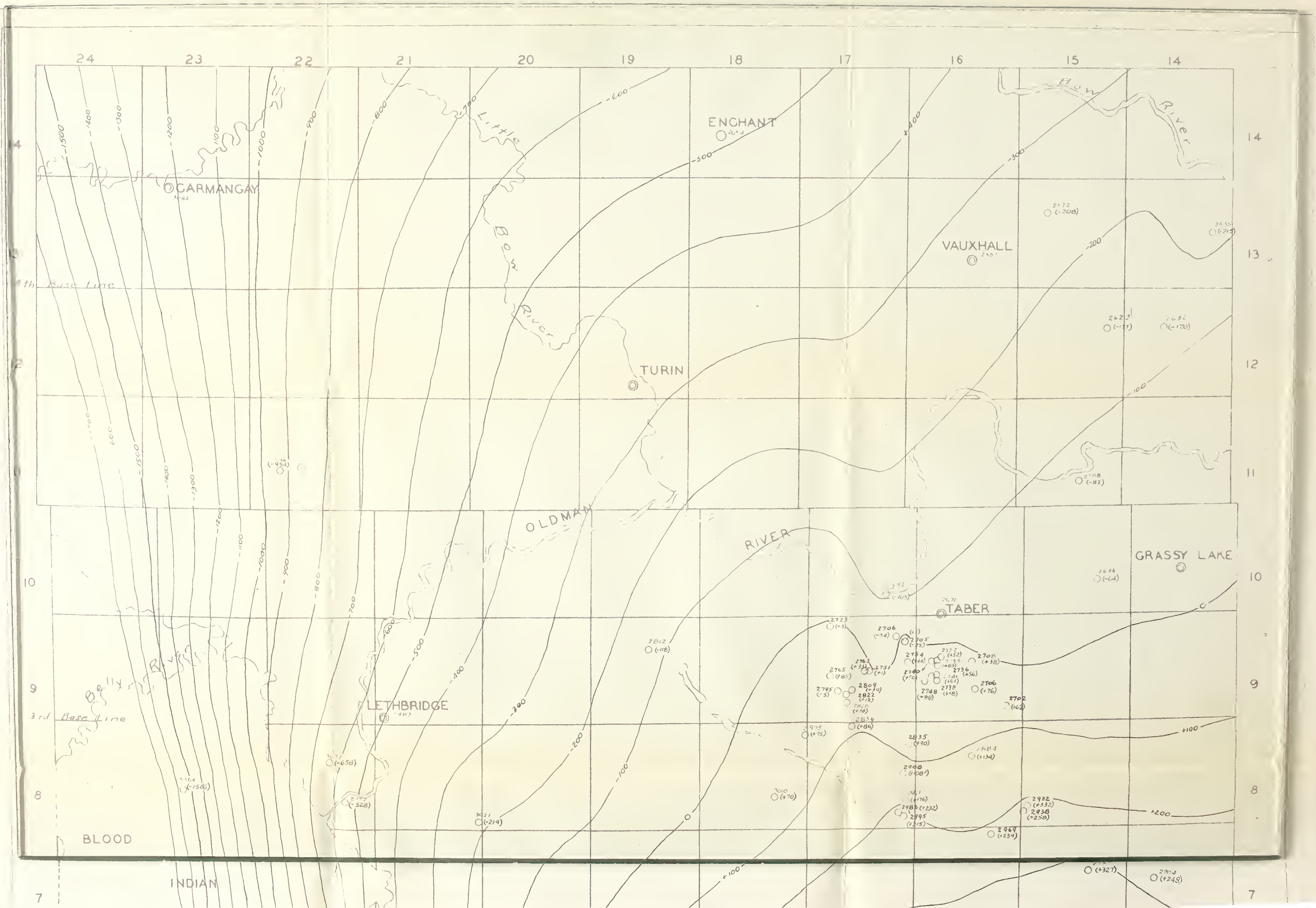
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ENCHANT
CARMANGAY
VAUXHALL
TURIN
GRASSY LAKE
TABER
LETHBRIDGE
BLOOD
INDIAN
Little Bow River
Bow River
OLDMAN RIVER
Belly River
4th Base Line
3rd Base Line
-1500
-1400
-1300
-1200
-1100
-1000
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
+100
+200
(-208)
(-215)
(-177)
(-170)
(-82)
(-64)
(-105)
(-454)
(-118)
(-658)
(-528)
(-1586)
(-219)
(+70)
(+75)
(+86)
(+90)
(+134)
(+62)
(+76)
(+38)
(+232)
(+215)
(+234)
(+332)
(+258)
(+327)
(+248)
2723 (+3)
2706 (-34)
2705 (-25)
2754 (+44)
2708 (+38)
2736 (+56)
2765 (+85)
2763 (+33)
2751 (+1)
2809 (+34)
2822 (+12)
2795 (-5)
2748 (+88)
2738 (+18)
2706 (+76)
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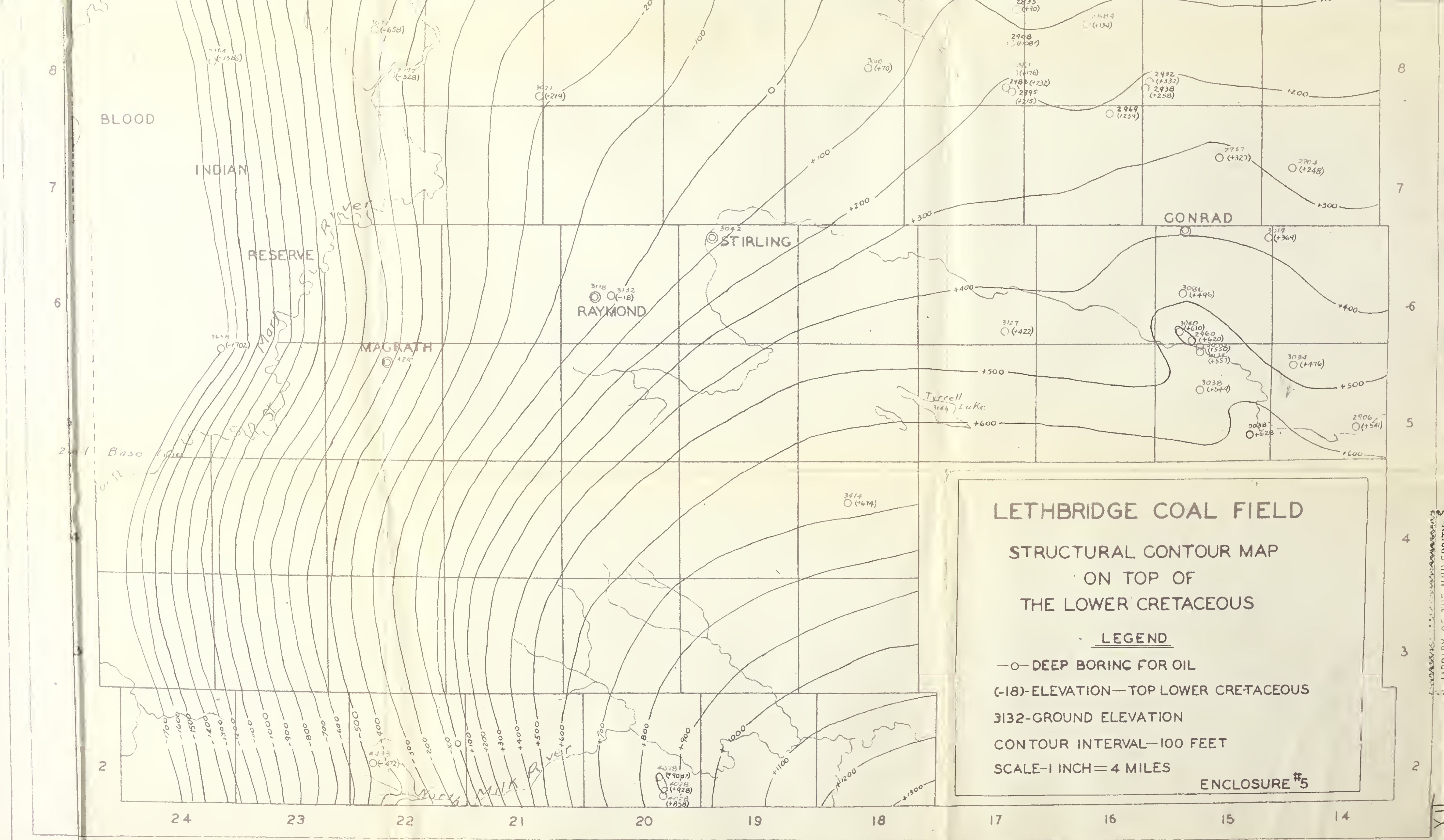
2982 (+332)
2938 (+258)



LETHBRIDGE COAL FIELD

STRUCTURAL CONTOUR MAP
ON TOP OF
THE LOWER CRETACEOUS

LEGEND

—o— DEEP BORING FOR OIL

(-18)-ELEVATION—TOP LOWER CRETACEOUS

3132-GROUND ELEVATION

CONTOUR INTERVAL—100 FEET

SCALE—1 INCH = 4 MILES

ENCLOSURE #5

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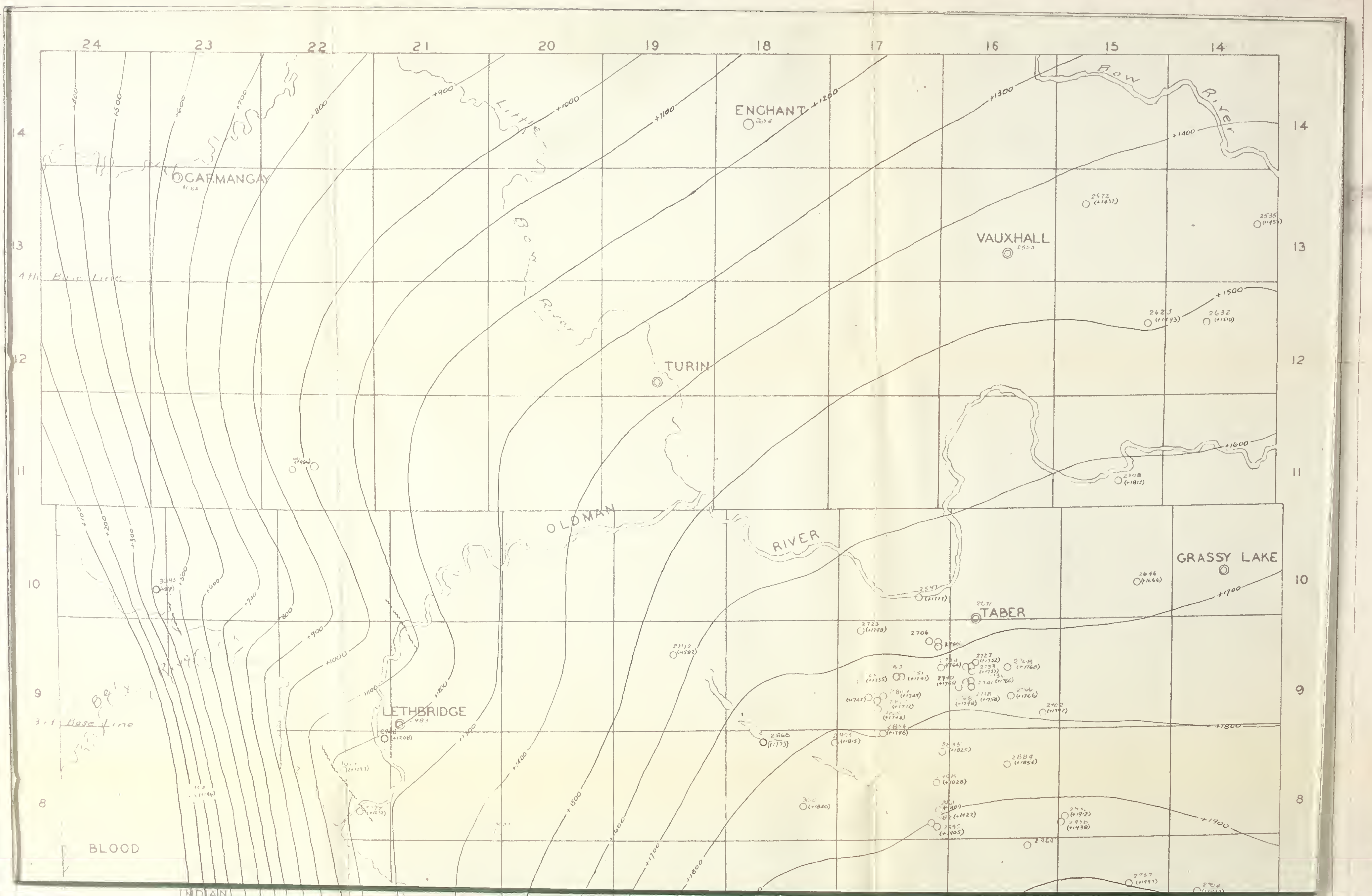
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ENCHANT
CARMANGAY
VAUXHALL
TURIN
TABER
GRASSY LAKE
LETHBRIDGE
BLOOD
INDIAN
Bow River
Little Bow River
OLDMAN RIVER
4th Base Line
3rd Base Line
+100
+200
+300
+400
+500
+600
+700
+800
+900
+1000
+1100
+1200
+1300
+1400
+1500
+1600
+1700
+1800
+1900
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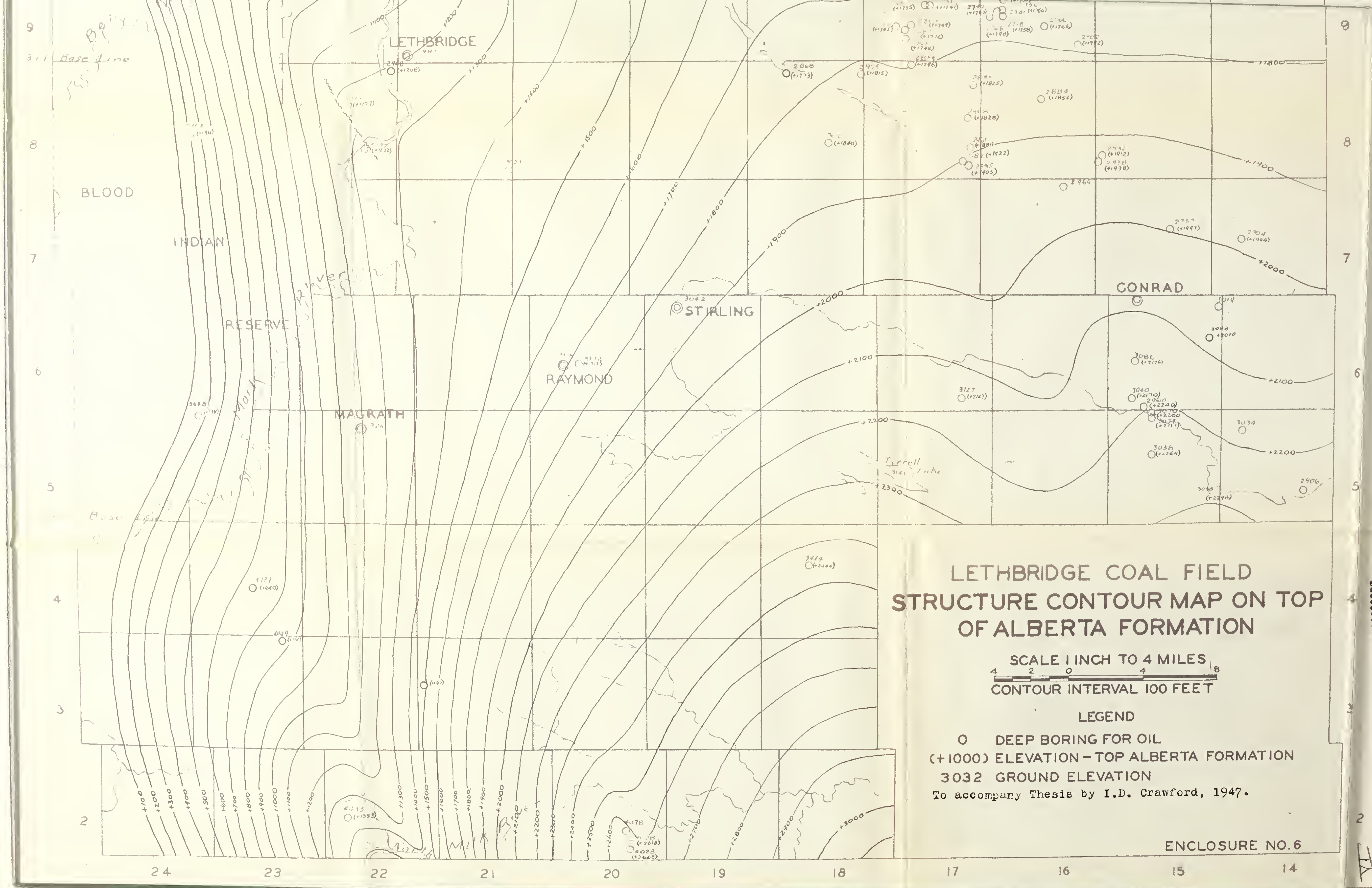

LETHBRIDGE COAL FIELD

STRUCTURE CONTOUR MAP ON TOP OF ALBERTA FORMATION

SCALE 1 INCH TO 4 MILES

4 2 0 4 8

CONTOUR INTERVAL 100 FEET

LEGEND

○	DEEP BORING FOR OIL
(+1000)	ELEVATION – TOP ALBERTA FORMATION
3032	GROUND ELEVATION

To accompany Thesis by I.D. Crawford, 1947.

ENCLOSURE NO. 6

LIBRARY OF THE UNIVERSITY OF ALBERTA

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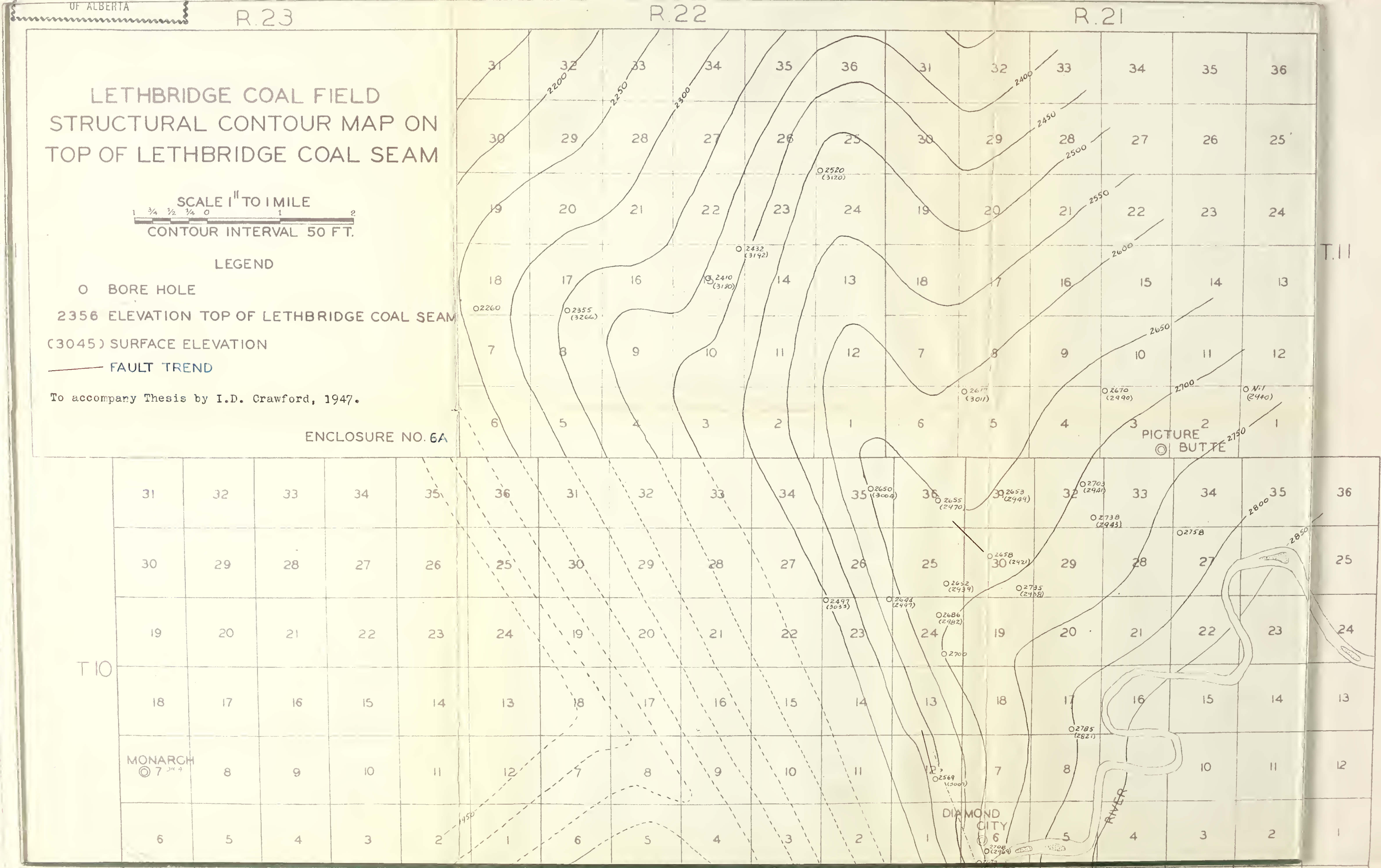
OF ALBERTA



LETHBRIDGE COAL FIELD
STRUCTURAL CONTOUR MAP ON TOP OF LETHBRIDGE COAL SEAM

SCALE 1" TO 1 MILE

CONTOUR INTERVAL 50 FT.

LEGEND

○ BORE HOLE

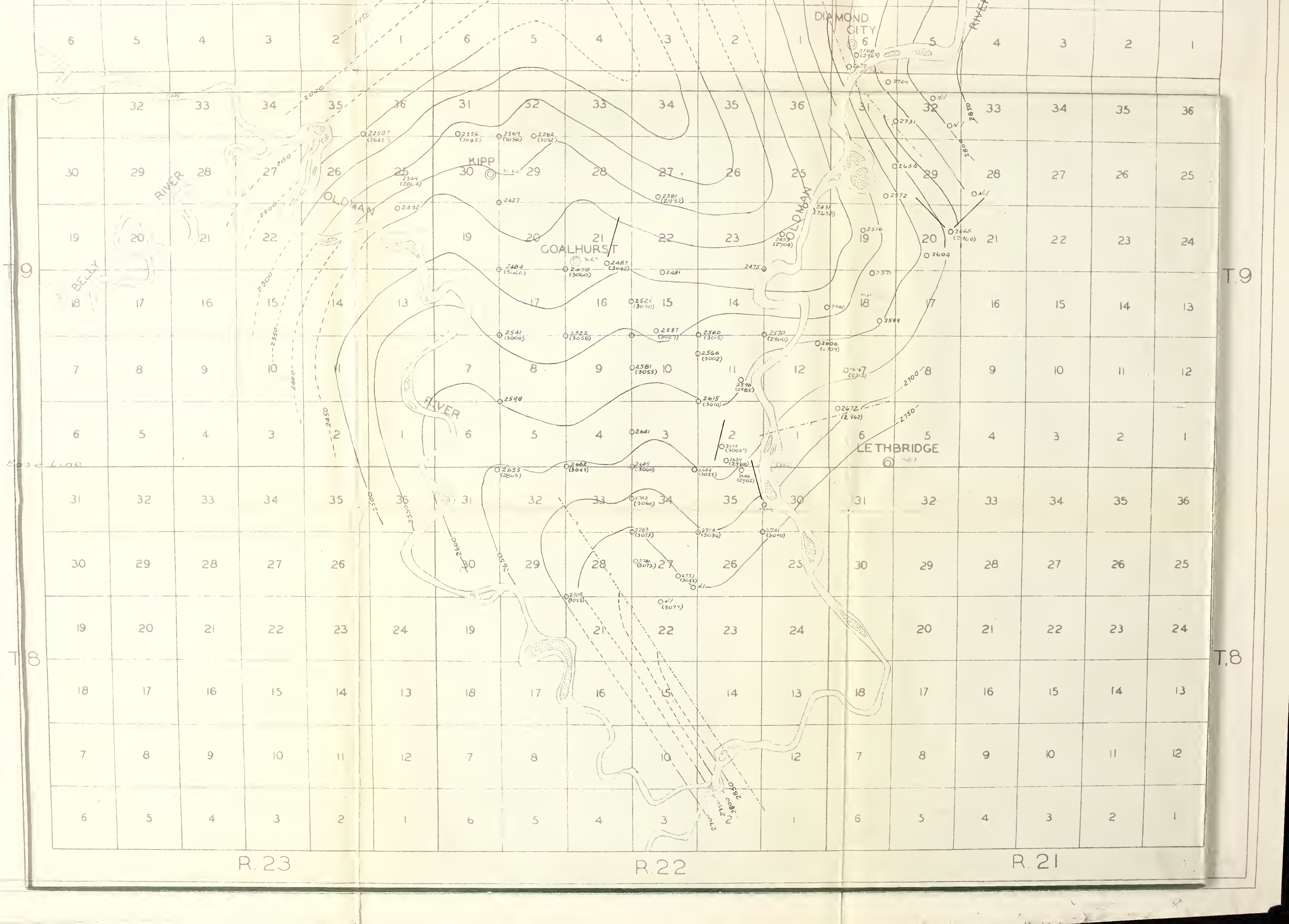
2356 ELEVATION TOP OF LETHBRIDGE COAL SEAM

(3045) SURFACE ELEVATION

——— FAULT TREND

To accompany Thesis by I.D. Crawford, 1947.

ENCLOSURE NO. 6A


DIAMOND CITY
KIPP
COALHURST
LETHBRIDGE
OLDMAN RIVER
OLDMAN
RIVER
BELLY
RIVER
T.9
T.8
R.23
R.22
R.21
3rd Base Line
2000
2150
2200
2300
2350
2400
2450
2500
2550
2600
2650
2700
2750
2800
2850
2250? (2645')
2356 (3045)
2364 (3050)
2382 (3032)
2324 (2844)
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2427
2381 (2993)
2431 (2652)
2457 (2704)
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2487 (3042)
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2541 (3000)
2522 (3058)
2537 (3027)
2560 (3015)
2566 (3002)
2570 (2960)
2581 (3055)
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2615 (3010)
2606 (2704)
2617 (2711)
2672 (2962)
2641
2613 (3005')
2624 (2988)
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2689 (3025)
2702 (3060)
2763 (3073)
2719 (3030)
2741 (3010)
2746 (3073)
2753 (3043)
2705 (3055)
N.1 (3077)
N.1
2708 (2969)
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2645 (2960)
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2571
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B29753